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Developing Countries and the Control of Climate Change: Empirical Evidence

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OF CLIMATE CHANGE:

Empirical Evidence

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Developing Countries and the Control of Global Climate Change: Empirical Evidence

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II.   Introduction[1]

The global control of anthropogenic climate change will require a complex cooperative effort among a large number of individual nations.   This cooperative effort will have to be based on a thorough understanding of how the various participating nations contribute to the process of global climate change, and how they are affected by that process.   On both dimensions -- contributions to climate change and effects from climate change -- there are huge uncertainties. The scientific understanding of climate change is itself at a very early stage. There are large disagreements among scientists about the effects of changes in greenhouse gas (GHG) concentrations on the global climate. Moreover, there are even larger unknowns about how individual countries and regions might be affected by global climate changes, since the implications of rising GHGs for climate patterns (including temperature, precipitation, storm patterns) and for material well-being (agricultural production, public health, physical comfort) are poorly understood at the country, regional, and global scales. Finally, there are important quantitative uncertainties about how countries have contributed in the past to changes in stocks of GHGs, and how they are likely to contribute in the future.

This paper aims to advance our understanding of several dimensions of this complicated problem. First, we use historical data and econometric evidence to assess the contributions of individual regions to the evolution of atmospheric concentrations of the main GHG, carbon dioxide, on a historical basis and on a prospective basis to the year 2050 assuming a "business as usual" scenario. Second, we use Nordhaus' (1998) estimates of regional damage functions to assess how various regions would be affected by global climate change according to these projections. Using these estimates, we then measure the proportionate contribution of each region to the overall rise in atmospheric carbon and the share of each region in the global damages resulting from rising carbon concentrations.

Our main conclusion can be put simply. For the temperate-zone economies, the contribution to rising carbon concentrations is much larger than the share of global

damages, while the reverse is true for the tropics. In effect, the temperate-zone economies are likely to impose severe net costs on the tropical regions. Since the temperate-zone economies tend to be rich, and the tropical-zone economies tend to be poor, global climate change represents a burden imposed on the poorer countries by the richer countries (this point was stressed earlier by Schelling, (1992) but without detailed quantitative estimates). Equitable solutions to the control of global climate change should take this inter-regional pattern into account.

We must stress again, however, that both the projections of carbon concentrations and their effects on individual regions are fraught with large uncertainties. The tracking of global carbon concentrations in the atmosphere is itself subject to huge scientific unknowns. When scientists have attempted to track the global carbon cycle, measuring emissions of carbon into the atmosphere and the re-absorption of carbon in various natural "sinks" (especially oceans and forests), there is a large amount of "missing carbon," in the sense that atmospheric carbon concentrations are considerably below what would be expected given the observed emissions of carbon into the atmosphere. (Fan et al 1998)

There is at least as much uncertainty concerning the possible damages from a given change in carbon concentrations. On the one hand, global climate models do not have enough resolution at the regional scale to assess the effects of global climate change on local patterns of rainfall, temperature, cloud cover, and storm patterns. On the other side, even if these things were known, their costs (or benefits) for human society would be extremely difficult to assess. Some aspects of rising carbon concentrations may provide net benefits to society, for example higher atmospheric carbon concentrations may help to fertilize crops in some regions. Rising temperatures may also extend growing seasons in some regions. In other parts of the world, however, the carbon fertilization effect may be small or non-existent, and higher temperatures may directly damage crop productivity. All of these costs and benefits will depend on the evolution of future technologies (e.g. the development of new crop varieties that are adapted to changing climatic conditions). Nordhaus' damage functions are heroic attempts to guess at the balance of these effects. They are very valuable as a first try, but they are undoubtedly very crude.

We proceed as follows: Section II presents empirical evidence on past trends of GHG emissions, both from fossil fuels and land use change (i.e., deforestation). In Section III we develop econometric estimates to model emissions. These estimates are used to make baseline forecasts for future emissions. Section IV reviews some of the evidence, sketchy as it is, about the relevant damages from climate change, again disaggregated among the developed and developing countries. Section V offers some concluding observations.

III.   Empirical evidence on GHG emissions

In this section, we introduce some scientific background and review the historical contributions from rising atmospheric carbon, first from fossil fuels and then from land use on an annual basis from 1860. Time series are available for emissions on a country basis for fossil fuel emissions and on a regional basis for land use change emissions. We summarize this data, and then model emissions using a panel data econometric model for fossil fuel emissions and a cross-sectional model for land use change emissions. This model serves as the means of predicting emissions, as explained in sections IV and V.

Scientific background

The main sources of anthropogenic CO_2 emissions are energy use and land use change, particularly deforestation. In 1996, emissions from fossil fuel use totaled 6.18 billion tons of carbon (Marland et al 1999). Emissions from land use change in the tropical world, including non-replacement timber harvesting, shifting and sedentary agriculture, and cattle ranching, have been estimated to be 1.6 billion tons in 1990 (Houghton and Hackler 1995). There is a great deal more uncertainty surrounding the measurement of emissions from land use relative to fossil fuels, and even greater uncertainty regarding other sources of CO_2 particularly livestock and solid waste. Other greenhouse gases contribute to global warming besides CO_2 including N_2O and CH_4 but these emissions and their contributions are poorly understood. Chlorofluorocarbons (CFCs) may also contribute to global warming but their emissions have largely been controlled and are no longer considered a significant source of concern. Because of the uncertainty surrounding non- CO_2 sources of global warming, as well as data limitations, we limit our analysis to fossil-fuel related CO_2 and CO_2 emissions from land use change.[2]

To model the process by which emissions are translated into atmospheric CO_2 concentrations, we follow Nordhaus (1998) closely. A system of equations (1-3) describes the "mixing" process by which the global stock of CO_2 cycles between the atmosphere ($M_{AT}(t)$), the upper reservoirs ($M_{UP}(t)$) and the deep oceans ($M_{LO}(t)$), where Em(t) is emissions at time t. At any point in time, atmospheric concentrations above the pre-industrial level of $M_{AT}*$ (approximately 590 GtC) lead to increased global surface warming through increased radiative forcing F(t) (equation 4). Finally, equations 5 and 6 model the process by which increased radiative forcings lead to temperature increases of the global surface and upper oceans ($T_{UP}(t)$) and the lower oceans ($T_{LO}(t)$) with lags

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2 This reasoning follows Nordhaus (1998) who limits his analysis to industrial CO_2 only, assuming a constant exogenous level of emissions from land use change.

resulting from thermal inertia.[3] These equations are as follows:

(1) $M_{AT}(t) = Em(t) + c_{11} M_{AT}(t-1) + c_{21} M_{UP}(t-1)$.

(2) $M_{UP}(t) = c_{22} M_{UP}(t-1) + c_{12} M_{AT}(t-1) + c_{32} M_{LO}(t-1)$.

(3) $M_{LO}(t) = c_{33} M_{LO}(t-1) + c_{23} M_{UP}(t-1)$.

(4) $F(t) = n\{ln[M_{AT}(t) / M_{AT}*]/ln(2)\} + Other\ Gas(t)$.

(5) $T_{UP}(t) = T_{UP}(t-1) + s_1\{F(t) - \lambda T_{UP}(t-1) - s_2[T_{UP}(t-1) - T_{LO}(t-1) - T_{LO}(t-1)]\}$.

(6) $T_{LO}(t) = T_{LO}(t-1) + s_3[T_{UP}(t-1) - T_{LO}(t-1)]$.

Ultimately, damages result from the level of T_{UP} at any time t. To model these damages, we use the quadratic specification developed by Nordhaus (1998b). He posits a relationship between $T_{UP}(t)$ and income loss of the form

(7) $DJ(t) = \theta_{1,J} T_{UP}(t) + \theta_{3,J} T_{UP}(t)^2$,

where $\theta_{i,J}$ is a region-specific parameter reflecting differential impacts of climate change. The regions for which this equation has been calibrated form the units of our own analysis. These regions are: Japan, USA, European Union (EU), "Other High Income," High Income Organization of Petroleum Exporting Countries (OPEC), Middle Income Countries, Russia, Lower Middle Income Countries, Eastern Europe, Low Income Countries, China, India, and Africa. [4] This equation and its parameterization are discussed in detail in section V.

We stress that the Nordhaus system of equations concerning the carbon cycle (1 −3) is fraught with considerable scientific uncertainty. There are large holes in knowledge concerning the cycling of carbon between the atmosphere, the oceans, and terrestrial biota (especially the overall biomass in forests). These equations do not solve the problem of the "missing carbon," so they do not provide a fully reliable way of translating from new emissions to long-term changes in carbon concentrations. Similar uncertainties plague the links from carbon concentrations to temperature (4 − 6), and from temperature to damages

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3 A complete discussion of these equations and the calibrations of the parameters are in Nordhaus (1998) and Nordhaus (1994).
4 A complete listing of the countries in each group is in Nordhaus (1998), or is available from the authors.

(7). Nonetheless, we applaud Nordhaus for constructing a workable system to analyze these issues, even as we warn ourselves against misplaced concreteness in our interpretation of the results.

Historical contributions to rising atmospheric carbon from fossil fuels

The Carbon Dioxide Information Analysis Center (Marland et al 1999) has estimated the global CO_2 emissions from fossil fuel use on a country basis beginning in 1751.[5] This data is summarized from 1860 in figure 2 and table 19. The associated stock accumulation is summarized in figure 3 and table 20. We calculated the annual stock using equations 1-3.

Non-OPEC high-income countries contributed forty-six percent of combustion emissions in 1996. Thirteen percent of total emissions came from Russia and Eastern Europe, and 15 percent came from China. Countries included in the Kyoto Protocol, the so-called Annex 1 countries of the Organization for Economic Cooperation and Development (OECD) Russia and Eastern Europe, accounted together for 59 percent of emissions. However, these shares are changing rapidly since emissions from Annex 1 countries are constant or falling, while emissions from developing countries (non-Annex 1) are growing at 6 to 7 percent per annum. Figure 2 shows that non-Annex 1 countries, accounting for 77 percent of the world population and only 37 percent of the world income in 1994, have been relatively insignificant contributors of CO_2 emissions until 1960. While CO_2 emissions from countries like China began rising rapidly, it was not until 1980 that the share of non-Annex 1 in world emissions began to account for a one quarter of global emissions from fossil fuels (see figure 2).

As the emissions path suggests, more than 85 percent of the atmospheric concentrations of CO_2 from anthropogenic sources were contributed by the Annex 1 countries over the past 100 years. Contributions from the developed world were negligible until the 1930s. While China has contributed about a third of the balance, it has done so mostly during the past 30 years.

These historical data suggest that the main drivers of CO_2 emissions are income growth and population growth. table 3 shows that with GDP growing at 6.22 percent per annum and population at 1.87 percent per annum during 1990-94, combustion emissions

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5 As national boundaries change so do the sources of CO_2 for the purposes of this calculation, so, the USSR is a single country and Germany is two countries until 1992. The following adjustments are also made: for 1960- 72 the Ryukyu Islands are added to Japan, for 1960- 69 Tanganyika and Zanzibar are combined, for 1960- 79 the Panama Canal Zone is added to Panama, for 1960- 69, Sabah and Sarawak are added to Malaysia, and for 1960- 69 North and South Vietnam are combined.

grew at 6.85 percent per year in developing countries. In contrast, developed (Annex 1) countries had a population growth of only 0.58 percent and GDP growth of 1.21 (or 0.86 in PPP terms) during the same period and their emissions fell by 0.64 percent (see table 7). Indeed, developed country emissions have leveled off since the early 1970s and began declining in the early 1980s, although the US and Japan (in contrast to Western Europe) had a relapse in the early 1990s (see figure 1). In per capita terms, Annex 1 countries emit more than five times as much CO_2 as non-Annex 1 countries (2.6 tons compared to under 0.5 ton). The disparity is even larger between low-income countries, which emit 0.2 tons per person, and high-income countries that emit 15 times as much per capita (see table 2).

Among low-income countries, particular "offenders" are often singled out as critical to the path of global emissions (see, for example Sathaye et al 1996). These include China, India, Brazil Indonesia, Mexico and South Africa. These are countries that have experienced high economic growth or that are regional leaders. Tables 8 and 9 report the emissions data for these countries as well as their basic summary statistics. It is not surprising that these relatively dynamic economies have high emissions but, as will be discussed below, this is a comparatively recent phenomenon.

If the main determinants of CO_2 emissions are income and population growth, another relevant consideration is the energy efficiency, or more precisely, the emissions intensity of the economy. When expressed in terms of CO_2 emissions per unit of GDP, emissions intensity is almost three times as high in non-Annex 1 countries than in Annex 1 (see table 2). However, when adjustments are made for differences in purchasing parity (one dollar buys 2-3 times as much in China than in the US), energy intensity is strikingly identical – 230 metric tons of CO_2 per million dollars of PPP GDP. This should surprise anyone who is familiar with the obsolete and patently inefficient power stations and vehicles in China, India and Africa. At least three factors may help explain this paradox. First, the Annex 1 emissions are inflated by the inclusion of Eastern Europe and Russia. Second, the non-Annex 1 income is inflated by the inclusion of relatively wealthy oil producers (Saudi Arabia, Kuwait, and other Gulf states). When we group countries in low income, middle income and high income economies as defined by the World Bank, we observe an inverted U-shape relationship between income and emissions. In 1994, emissions were 206 tons per million dollars of PPP GDP for low-income countries, 234 tons for middle income countries and 14 tons for high-income countries (see table 3).

Besides income and population, Another factor that may play a role in determining a country's annual emissions is the different heating needs between temperate and snow-ice climates on the one hand and tropical and subtropical climates on the other. Since almost all Annex 1 countries are temperate and most developing countries are in the

tropics or subtropics, the latter ought to have lower heating needs and therefore lower energy use per unit of GDP than countries in temperate and snow-ice environments. For example, when we classify countries by climate, we find that temperate countries emit 238 tons per million dollars of PPP GDP and non-temperate countries 196 (see table 5). Therefore, equality of emissions intensity of Annex 1 does not necessarily imply equal energy efficiency in the production of GDP. Rather, much of this energy is being used for heating.

In summary, a review of the historical data regarding CO_2 emissions from fossil fuel usage suggests that while the developed world is disproportionately responsible for the current stock, the role of the developing world is increasing. The particular prominence of China is also notable. Sorting the current emissions by income and geographic distinctions suggests that income, population, and climactic zone may be the main determinants of a country's emissions over time. We test this proposition below. We find that this hypothesis is largely confirmed, and use the econometric equation developed as the basis for projecting emissions from fossil fuels from 1996-2050 in the next section.

Fossil fuel emissions model

Here we attempt to estimate a simple relationship between per capita CO_2 emissions (c), expressed as thousands of metric tons of carbon, and per capita income (y), expressed as 1985 purchasing power parity (PPP) dollars. Both variables are expressed in logarithms:

(8) $\ln(c_{it}) = a_i + \beta_t + F[\ln(y_{it})] + \varepsilon_{it}$.

The index *i* refers to countries and *t* refers to time in years. The set of parameters a_i reflects country-fixed effects, that is, persistent differences across countries in climatic conditions, fossil fuels and renewable energy endowments, in preferences, in economic structure, in regulations, and the like. The set of parameters β_t reflect changes over time such as changes in world oil prices, in technologies and in environmental policies as well as in preferences unrelated to income levels. The *F(•)* is a flexible functional form in *y*. Following Schmalensee, Stoker, and Judson(1998), we employ a piecewise linear spline function, which allows for distinct elasticities of emissions with respect to output in each segment of the spline function. A log-linear specification was chosen because country and time-fixed effects are more likely to be multiplicative than additive and also because tests performed in previous studies (Holtz-Eakin and Selden 1995) found no significant differences between linear and log-linear specifications. The last term in equation 8 is a

stochastic error term that must be uncorrelated with the independent variables for ordinary least squares or "random effects" panel data estimation to produce consistent parameter estimates.

We test the hypothesis that income, population, and climate zone are the primary determinants of country's emissions in the following manner: In step 1 we estimate equation 8 econometrically. To do this we use dummy variables for (T-1) of the years for which data is available. This so-called "least-squares dummy variable" (LSDV) estimation has the effect of controlling for year-specific effects that are unmeasured or unobservable. We then estimate the equation assuming that the error term is independent of the independent variables and assuming that it is correlated with them. A Hausman test confirms that the fixed effects model, which allows $E(x_{it}\varepsilon_{it})$ to differ from zero, is in fact correct (Hausman 1978, Hausman and Taylor 1981). These regressions and the specification test are reported in tables 10-12.

A brief discussion of the use of the fixed effects regression is needed to explain the possibilities for testing our hypothesis. The LSDV technique can be followed for the country-specific effects. "Within" regression, which is equivalent to using (N-1) country indicator variables, would control for time-invariant country effects, which are not included as independent variables. This would ensure that the coefficients on time variant variables such as income are consistent, provided the model is correctly specified. However, the shortcoming of this specification is that no coefficients on time-invariant variables can be determined. This is problematic if the variables of interest are unchanging over time, as climate zone is. To estimate the coefficients on variables such as climate zone two options are available. These are (1) a random effects model, appropriate only if $E(x_{it}\varepsilon_{it}) = 0$, meaning that the unobserved variables are not correlated with income, and (2) the use of instrumental variables to control for such correlation. A necessary condition for this second possibility is that the equation must have at least as many exogenous time-varying variables as there are endogenous time-invariant variables (Hausman and Taylor, 1981).

Unfortunately, the use of instrumental variables is not feasible in our case. We require a simple, reduced-form equation for forecasting purposes, and any time-varying variables that are included in the forecast equation must themselves be forecast. This would add additional uncertainty for potentially little value. The random effects model would be ideal; as shown in table 10, it provides coefficient estimates for both the income spline and the time-invariant structural variables. However, these coefficient estimates are not consistent or efficient estimates of the true parameters if important unobserved time-invariant effects that are correlated with the independent income variables remain

after those in table 10 are accounted for. These other effects are included in the error term and, as such, the assumption $E(x_{it}\varepsilon_{it}) = 0$ does not hold. The Hausman specification test in table 11 confirms that this is the case. The fixed effects model must be used for forecasting. We present the random effects equation here to make a limited, primarily qualitative, discussion of time-invariant determinants of fossil fuel emissions possible.

Fossil fuel emissions data

For the econometric estimation, we combined time series and cross-section national level data to construct a panel with 3,869 observations for the period 1960- 92, of which 985 are for Annex 1 and 2,884 for non-Annex 1 countries. Our data set for income, population and emissions is quite similar to that of Holtz-Eakin and Selden (1995) and Schmalensee, Stoker, and Judson (1998). Our sample includes 127 countries accounting for approximately 95 percent of the world population and 90 percent of the global CO_2 emissions from fossil fuels.[6] These countries are those with population over 1 million for which emissions and income data are available.[7] The population and hydroelectric production data (measured in megawatts) are from the World Bank Development Indicators (1998) and World Bank (1992). GDP in ($1985) PPP terms is taken from the Penn World Tables (Summers and Heston 1991), updated for 1992, and the CO_2 emissions data are from Marland and others (1999). Energy prices and renewable energy consumption data for developed countries are obtained from OECD (1994).[8] Population by climatic zone data is based on the Koppen-Geiger-Pohl (Geiger and Pohl 1953, Geiger 1954) system of classification, using population data from Tobler and others (1995).

Fossil fuel emissions findings

As explained above, we first estimated equation 5 using a random-effects specification. Using a random effects specification also allows us to estimate the coefficients on such structural variables as percentage of population is temperate, wet-dry and snow-ice climate zones. We also estimated the coefficients on a dummy variable for

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6 Please see the earlier note discussing the treatment of changing national boundaries for this analysis.
7 The following countries have population over 1 million and are excluded from our analysis because of a lack of readily available data: Afghanistan, Albania, Cambodia, Lebanon, Libya, Cuba, Vietnam, Namibia, Lesotho, Taiwan, North Korea. Unlike Schmalensee, Stoker, and Judson (1998) we have not supplemented the Penn World Tables income data from other sources. We also exclude United Arab Emirates, Saudi Arabia, and Kuwait as outliers, similar to Holtz-Eakin and Selden (1995).
8 Energy price data for Asia as calculated by the ADB (1992) was also reviewed but is not used here because weighted end-user price includes bundled distribution and transmission costs.

whether the country is an energy-exporter,[9] and whether it has had a socialist government.[10] These results are shown in table 10.

This equation suggests that climate may have significant predictive power. Temperate climate may result in higher CO_2 emissions per capita and snow-ice climates may have a similar effect, presumably because of heating requirements. Energy exporters may have higher CO_2 emissions per capita, because of refining activity, while countries that produce relatively higher levels of hydropower emit relatively less. Our hypothesis is that socialist countries should have relatively high levels of emissions for their income level because of their energy-intensive development path. This regression suggests that this may be the case.

While the coefficient estimates in this regression do agree with theory, as discussed above, a Hausman test (table 11) confirms that they are not consistent estimates, since there is evidence that other fixed country effects should be included as independent variables, and that these excluded fixed effects are correlated with the included variables. In the regressions that follow, we drop the fixed effects that we have explicitly included in the regression, and simply include a vector of country-fixed effects dummy variables. This allows us to estimate the coefficients on the income spline function consistently, even though we can no longer determine separate coefficients on the climate variables.

Having confirmed that a fixed effects specification is correct, we re-estimated equation 8 with three alternative spline functions, 5 segments, 10 segments, and 12 segments. Based on significance levels we chose the 10-segment specification. Estimations of the 10-segment spline with 3,869 observations from 127 countries explained 61 percent of within country variation and 81 percent of the between country variation. Overall 75 percent of the variation was explained. The results of this estimation of the CO_2-income relationship is reported in table 12 and graphed in the associate figure. For all segments except the first, the estimated income elasticity was

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9 The following countries are energy exporters at the end of the period: Angola, Argentina, Australia, Azerbaijan, Benin, Bolivia, Canada, China, Cameroon, Congo, Rep., Columbia, Algeria, Ecuador, Egypt, Gabon, U.K., Iran, Iraq, Khazakstan, Laos, Mexico, Malaysia, Nigeria, Norway, Poland, Paraguay, Russia, South Africa, Syria, Turkmenistan, Trinidad and Tobago, Turkey, Venezuela, Vietnam, and Yemen. (World Bank 1997)
10 The following countries are considered to be socialist for all or part of the period under consideration: Soviet Union, Mongolia, Albania, Yugoslavia, Bulgaria, Czechoslovakia, Hungary, Poland, Romania, North Korea, China, East Germany, Vietnam, Cuba, Congo, Rep., Algeria, Iraq, and Syria (Kornai 1992). If the period of socialism as defined by Kornai (1992) is longer than ten years, we consider the country socialist for the entire period of analysis under the assumption that the effects of the regime on the economy will be sufficiently profound as to persist beyond the nominal change in government.

statistically significantly different from zero at the 95 percent level. [11]   The income elasticities of emissions were positive for income levels below $7,700. The elasticities become negative as incomes rise above that level. The largest elasticity is 1.05, and occurs for per capita incomes in the range of $921- $1410. An income elasticity of emissions greater (smaller) than one means that a one percent increase in income increases emissions by more (less) than one percent. A negative elasticity means that further increases in income levels per capita result in reductions of emissions per capita.

Our findings, suggest an inverted U-relationship between income per capita and CO_2 emissions per capita. As income increases from very low levels emissions increase at an increasing rate; they reach a plateau at an intermediate level of income beyond which additional increases in comes result in smaller additions to CO_2 emissions until they turn negative. This inverted U-relationship has been found by several other authors in relation to local and regional pollutants (Grossman and Krueger 1995, Selden and Song 1994, and Panayotou 1993 and 1997), and was termed the environmental Kuznets curve because it resembles the relationship between income and inequality hypothesized by Kuznets (1955). The implication of such a non-monotonic relationship between pollution and income level is that income growth is both a cause and a cure of environmental problems, a property that is not unreasonable for local pollutants.

Finding an inverted U-shaped relationship for an invisible global pollutant with much delayed effects and ample scope for free riding is a bit puzzling but fully explainable by the structural changes accompanying economic growth: from agriculture to industry to services. Previous studies including Holtz-Eakin and Selden (1995), Schmalensee, Stoker, and Judson (1998), and Galeotti and Lanza (1999) found a similar inverted U-relationship. The latter two studies found a turning point (where emissions per capita stop increasing and begin to fall with income growth) in the range of $10,000 to $17,000 compared to around $35,000 in the former study. This is a significant finding since it suggests that CO_2 emissions will not continue growing linearly with income but will slow down, level off and even decline once a certain level of economic development is attained.

Besides income, another variable that is likely to be a significant determinant of CO_2 emissions is the price of energy. Unfortunately, there are no complete time series and cross section data on energy prices for our country sample. Conspicuously absent are energy price data for Africa, and the limited data available for Asia and Latin America

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11 Tests for heteroskedasticity suggest that there is some tendency for countries with higher incomes to have smaller squared residual estimates. The use of robust standard errors and LSDV estimation does not change the coefficient estimates and does not alter the significance of any of the coefficients either. We present the OLS results here.

are not comparable by construction to the available OECD information[12.] Thus, we have been unable to estimate a global emissions model with energy prices. Of course, changes in the world prices are reflected in time fixed effects, and persistent domestic price differences among countries are reflected in the country fixed effects, but the lack of comparable data prevents us from estimating what part of fixed effects is accounted by energy price differences between countries.

In an attempt to make the best of the limited energy price data available to us, we re-estimated 10-segment spline functions separately for the OECD. The results are reported in table 13. Naturally, the first six income segments were dropped from OECD since no OECD country has incomes under $10,000 per capita. Given the small sample of countries, the absolute magnitude of the coefficients (elasticities) should not be taken seriously despite the good fit. However, the signs of the energy price estimated coefficients are negative, as one would expect. The coefficient estimate for renewable energy consumption per capita is positive, which is certainly counter-intuitive, but it is also not significantly different from zero.

To sum up, income growth drives CO_2 emissions, but the relationship is not a linear or monotonic one. The income-emissions relationship varies along a country's development path both quantitatively and qualitatively. At the earlier stages of development, where all non-Annex 1 countries, except the oil producers, find themselves today, emissions rise with income growth; and for the poorest among them, they rise at in increasing rate. At a later stage of development, where most Annex 1 countries find themselves, CO_2 emissions level of and decline with further economic growth. The implications of this result are profound for both emissions projections and formulations of policies to control climate change, as shown below.

While further research is needed to fully explain the country fixed effects, the fixed effect estimates themselves are indicative of the countries that are significant outliers in the sense that they have unduly high (or low) emissions given their level of development (as reflected by income per capita), their geographic location and the structural characteristics of their economy. Major countries among positive outliers (excessive emissions) are United States, Canada and Eastern European Countries such as Romania. Countries with small fixed effects include Laos and Nepal. Schmalensee, Stoker, and Judson (1998) suggest that this result may be attributable to the fact that income is poorly measured in these countries (see table 14a for a complete list of the country fixed effects). It should be kept in mind that this ranking is based only on CO_2 emissions from

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12 The Asian figures are not comparable with the OECD and Latin American figures because the weighted average energy price calculated by ADB for Asia includes the bundled electricity costs to the end users (including transmission and distribution costs) rather than the costs of fuel to power producers.

fossil fuels. Inclusion of emissions for land use changes is not expected to significantly change these results since land use emissions account for only 20 percent of the total. Possible exceptions include Brazil, and Indonesia, which have been experiencing significant forest loss and land conversion.

Historical contributions of rising atmospheric carbon from land use changes

The burning of fossil fuels for energy is the main but not the only source of CO_2 emissions. Land use changes, mainly in the form of deforestation and forest land conversion to other uses contribute currently about 20 percent of the global CO_2 emissions from anthropogenic sources. tables 17 and 18 report, respectively, the CO_2 emissions (flows) and concentrations (stocks) from land use change during the period 1860-1990. The same information is shown graphically in figures 4 and 5 from which is clear that land use change has become a significant source of CO_2 emissions only in the last four decades and tropical developing countries have been the main source. Developed countries have been net sequesters of carbon (negative emissions) at least since 1980.

The historical path of these emissions, on the other hand, is much different than the current picture. In the 19th century, deforestation and hence CO_2 emissions from land use change was nearly twice as high in the temperate countries of Annex 1 as in the rest of the world. During the first three decades of the 20th century, roughly the same amount of CO_2 (about 300 million tons) was released from Annex 1 and non-Annex 1 countries. Since 1930, temperate deforestation, which remained constant for almost a century, began to slow down rather rapidly, while tropical deforestation began to accelerate and rose steeply between 1940 and 1970; it leveled off in the 1980's and 1990's. Regionally, Europe was the first to deforest in earlier centuries and by 1850 deforestation was already slowing down, which North America continued to experience increased deforestation until the turn of the century. Since 1940, all tropical regions experienced rapid deforestation but tropical Asia soon began to level off while Latin America and Africa continued to deforest at high and increasing rates until the 1980's.

Tables 15, 15a 15b contains data on deforestation in 1990 and 1995. This table is intended to highlight important forest use phenomena and the major deforesters. Since land use change is relatively poorly understood, identifying the major sources of land use change emissions is important; if the problem is concentrated in a few countries, abatement and research efforts can be more effectively directed. A comparison of tables 15 and 15b shows that land use change is almost entirely a tropical world phenomenon. Even wood product exports are higher in the temperate world than in the tropics. Moreover, table 15a shows that that almost 75% of all emissions from land use come

from 9 countries, all in Latin America and Tropical Asia. The problem, while of uncertain magnitude, is almost certainly localized.

Land use emissions data

Houghton and Hackler (1995) provide an estimate of regional land use change emissions from 1860- 1980 for North America, Europe, the Soviet Union and Japan, and from 1860- 1990 for China, India, Tropical South and Southeast Asia, Latin America and Africa. We supplement this data with OECD emissions estimates from the United Nations Framework Convention on Climate Change (1997) and developing country estimates from WRI (1997). [13]

To use the Nordhaus damage equation, we must estimate emissions for the regions for which the equation has been calibrated. As such, the Houghton (1994) data must be placed into the Nordhaus categories. This was done on the basis of annual deforestation data. This data is from FAOSTAT for 1961-1990, and Zon and Sparhawk (1923) for earlier in the century. Like Houghton and Hackler (forthcoming) we assume that deforestation begins in 1750 and increases linearly until 1900.

Land use emissions model

In order to project CO_2 emissions in the future we must understand the factors behind the dramatic shift in rates of deforestation and hence forest cover between regions and over time. Unfortunately, reliable time series on deforestation and forest area are not available. FAO (various years) report data on forest area for 1960, 1980, 1990 and 1995 but they are not strictly comparable except for the last two years. Emissions at the country level are not available on an annual basis either, though they are estimated by WRI for 1991, for developing countries only. We have, therefore, limited ourselves to cross-section analysis of the 1991 emissions.

The main sources of deforestation are forest land conversion to shifting cultivation and sedentary agriculture and unsustainable fuelwood collection and wood harvesting. Since both of these sources of land use change depend on population density, we specify the following regression equation for explaining variation of forest cover across countries:

(9) $\ln(\text{emissions/ha})_i = a_o + a_1 \ln(\text{population density})_i$

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13 Houghton and Hackler (forthcoming) states that the 1994 figures used here are approximately 30% too low based on revisions to his methodology. Unfortunately, revisions have been made public only for South and Southeast Asia, to our knowledge.

$$+ a_2(\ln(\text{population density}))^2{}_i + a_3(\% \text{ change in population density})_i$$
$$+ a_4 \ln(\text{forest cover/ha})_i + a_3(\text{dummies for climate and regions}) + \varepsilon_i$$

Equation 9 was estimated using least squares regression techniques allowing for heteroskedasticity. The results are reported in table 16. As expected, higher population density results in loss of forest cover, though at a decreasing rate. Perhaps because this sample is for developing countries only, income per capita does not have a coefficient estimate that is significantly different from zero. This is not consistent with historical evidence, which has shown developing countries to be aforesting as their incomes increased. Among the climatic variables, only the percent of land in temperate zones had a significantly negative effect on forest cover, reflecting the fact that these regions are less well endowed with forest cover to begin with. The percentage of people in rainforest zones is estimated to increase emissions from land use change, possibly reflecting firewood use and slash and burn agriculture in these regions. We will employ the results of this estimation in our projections of future CO_2 emissions from land use change.

Since equation 9 estimates emissions, for prediction purposes this must be translated into lost in forest cover. Methodologies for making this transformation are complicated and have arrived at very different results. See Houghton (forthcoming) for a concise summary of the varying estimates of emissions from tropical Asia. Calculating emissions from land use change requires assumptions regarding the use and type of the wood deforested, and the treatment of the land in question after deforestation occurs. We have used a simple transformation method, suggested by WRI (1997). Change in forest cover in hectares is transformed to metric tons of biomass per hectare by multiplying lost forest cover by the 140, 120, or 53 tons of biomass per hectare depending on whether the majority of a country's forests are tropical, temperate or boreal. The carbon content of this mass is then assumed to be 45%, 5% of which is sequestered in soil. Of the remaining carbon, 25% is assumed to be used for long-term construction, based on sawn wood and roundwood production in tropical countries in 1994 as calculated by the FAO (1997). The remaining carbon is emitted.

It is clear from the proceeding discussion that the prediction of emissions from land use change used here is extremely imprecise. The data used for prediction are cross-sectional, so that there is a potential that that residual error term is correlated with the independent variables. The data are also for developing countries only, so that the effect of income growth on deforestation cannot be accurately modeled. Nonetheless, there is a limit to the amount of error we are introducing into the forecasts of long-term carbon concentrations, because there is an upper limit to the amount of emissions that may occur as a result of land use change, i.e. the emissions that would result from total deforestation. While it is certainly not a policy prescription (!), table 15c shows the effect of cutting down the *entire* tropical forest at a linear annual rate by 2050. We estimate the additional

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stock *above the 1990 level* to be approximately 85 GtC While the loss of the forest would be disastrous for many reasons, it would not hugely affect the stock of atmospheric CO_2 as of the middle of the next century, *ceteris paribus*. We proceed with projections using equation 9 and the data we have discussed, with the caveat that the land use emissions estimates are subject to a higher proportionate range of uncertainty than those for fossil fuels are.

IV. Projections of CO_2 Emissions to 2050

Fossil fuel emissions

Having explained historical emissions, we use the econometric estimates to project emissions and concentrations to 2050. In projecting CO_2 emissions from fossil fuels, we use our parameter estimates from the income spline function assuming that the income elasticity of emissions estimated for the last spline within our sample applies to all higher income levels. For population, we use the average of the low and medium UN projections (1996).

To forecast income we make the following simple assumption. We assume that the U.S. economy grows at a rate of 1.5% annually each year. For other countries, we construct our own growth projections based on the following partial convergence equation:

(10) $gap_t = 0.98 gap_{t-1}$; where $gap_{t-1} = \ln(y_{i\ t-1}/A_i\ y_{USt-1})$.

The parameter A is defined in the following manner:

(11) $\ln (A_i) = -0.5\ (Tr_i) - 0.5\ (L_i) - \ln (0.7)$,

Where Tr is the percentage of a county's land in tropical ecozones and L is a dummy variable for non-European landlocked countries.

The logarithmic income gap between country i and the United States closes at a rate of 2 percent per year, so that the logarithmic gap at year t equals 0.98 of the logarithmic gap at year t-1. According to this specification, developing countries attain at most 70 percent of the U.S. income level, with non-European landlocked and tropical countries falling further below that level. Countries that currently have incomes greater than 70% of the U.S. per capita income (i.e., the OECD and other high-income countries) experience full convergence with the logarithmic income gap shrinking by 2 percent each year. The coefficient A_i is introduced to take into account those fundamental

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considerations (e.g. physical geography) that may limit full convergence between country i and the United States.[14] We assume that the GDP per capita of country i converges to a long-run level equal to $(A_i *y_{US})$, where y_{US} is the income level of the United States. In particular, we assume that being tropical or landlocked reduces the long-run income level by another 40 percent $(0.40 = 1 – \exp(-0.5))$, and being both landlocked and tropical by 64 percent $(0.64 = 1 – \exp(-0.5)*\exp(-0.5))$.

For forecasting purposes, we require a time trend that will capture energy productivity gains that lower emissions per unit of GDP at a given level of income. The time-fixed effects in our basic equation contain both changes in productivity and real price energy changes since the real price of energy is not included as an independent variable in the equation. Evidence for the inclusion of price effects in the time fixed effects is provided by the fact that the time-fixed effects exhibit an upward trend, with a leveling off in the early 1970s.[15] This change in slope coincides with the large change in world oil prices as a result of the oil crisis. We need to separate the price and productivity trends in the fixed effects, but are unable to do so for the entire sample because of a lack of energy price data. We do have energy price data for the OECD, and so can obtain a pure productivity effect for this sub-sample as the coefficient on a time variable. When the equation is run for the OECD alone, *including prices*, the coefficient on time is negative (-0.01) and significant. This represents productivity changes. We use this coefficient from the OECD-only regression to supplement the income spline coefficients to forecast emissions for the entire sample. Since prices are excluded from the forecast, we make the implicit assumption that the real price of energy is constant for the period under consideration.

Using the income projections calculated from equations 10 and 11, and the earlier spline estimates, table 21 reports the projected flows of CO_2 from fossil fuel emissions between 1990 and 2050 for the major regions under consideration, as well as world total. Historic and projected flows from 1860-2050 are shown in figure 11. As seen from the table, U.S. emissions decline steadily from 1.4 billion tons of C in 1990 to 0.85 by 2050. Chinese emissions increase from 0.92 billion tons to 1.79 in the same period. Globally, emissions increase from 6.18 to 7.01 billion tons of carbon equivalents. The stocks of CO_2 emissions continue to grow for all regions: for developed countries they increase by one-half 2050, while for China, India and the rest of the world, they increase by almost ten times. India experiences the greatest increase, but its emissions are still only a fraction (a third) of Chinese emissions. The projected stocks and flows are shown graphically in figures 6 and 7. The total stock of anthropogenic CO_2 emissions in the atmosphere is

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14 For a discussion of these considerations, see Gallup, Sachs, and Mellinger (1998).
15 This is shown graphically in Schmalensee, Stoker, and Judson (1998).

projected to reach 415 billion tons of carbon equivalents, almost three times the 1990 levels (see table 22 and figure 6).

Land use emissions

CO_2 emissions from land use sources are projected to the year 2050. We use the population and income projections described previously. We use the population projections we use for forecasting CO_2 emissions from fossil fuels. The projected emission flows from land use changes are reported in table 23 and figure 8 for the so-called "Nordhaus regions." Total flows from 1860-2050 are shown in figure 12. Developed countries continue to act as a net sequester of carbon through reforestation at the rate of about 200 million tons a year while the rest of the world reduces its emissions from about 1.5 billion tons in 1990 to less than 1 billion tons annually by 2050.

The stock of emissions from land use in the atmosphere all but disappears for Annex 1 countries; for the rest of the world the stock increases very slowly (table 24 and figures 9 and 13). As discussed previously, this suggests that land use changes as a source of emissions all but disappears by 2050 under a business as usual scenario, provided that developing countries continue growth at historical levels. Therefore, efforts to control climate change should focus on the consumption of fossil fuels rather than on land use change. This does not mean that the control of reforestation is not a worthwhile investment for other reasons such as biodiversity conservation and watershed protection. Recognizing and internalizing the carbon value of forests may play a critical role in efforts to conserve forests under threat or to reforest deforested areas. Controlling deforestation may not save the climate but efforts to control climate change may save forests from both unsustainable uses and climate change itself.[16]

Total CO_2 emissions projections

Given the projected decline of deforestation and associated land use emissions over the next 50 years, the projections of total CO_2 emissions and their accumulated stocks in the atmosphere are not very different from the projected flows and stocks of emissions from fuel combustion. As seen in table 26 and figure 15, total stock of CO_2 emissions for the world (including the natural stock of 590 GtC) at 2050 is projected to reach almost one trillion tons of carbon equivalent. The land use contribution is only about 73 billion tons. Two notable observations are the constancy and slight decline of the CO_2 emissions from Annex 1 and the very rapid growth of Chinese emissions (see

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16 The caveat to this conclusion has been noted; there is a high degree of uncertainty regarding emissions from land use change and deforestation.

figure 14). In terms of stocks, figure 15 shows that Annex 1 continues the leveling off that began in the 1990s while China and the rest of the world begin to dominate even in stock terms past 2030, accounting for about 60 percent of global stocks in 2050.

Table 26 must be placed in the context of the econometric equation used to estimate emissions from fossil fuels. Unlike Nordhaus (1998) the spline function used here does not constrain the income elasticity of emissions to remain fixed at unity. Rather, the elasticity responds to income. As a result, we estimate flows of CO_2 that level off by 2045, relative to Nordhaus' forecast (see figure 16). As the figure shows, the flows we forecast are higher than those predicted by Nordhaus (1998) until around 2035. This is because our treatment of flows from land use change is different than his and also because of the environmental Kuznets curve emissions path that we employ.

Our forecast emissions path results in a higher predicted stock of CO_2 by 2045 relative to Nordhaus, and thus a higher temperature increase. Relative to 1990, we predict a 1.3-degree increase in temperature, while Nordhaus predicts a 0.83-degree increase relative to 1990 levels as a base case. Our forecasts both suggest that in 1990 the global mean temperature had increased by approximately 0.43 degrees relative to 1900. Not only is our prediction of the stock of CO_2 in 2045 higher than that of Nordhaus, it is higher than the main scenario of the IPCC, IPCC-92a (IPCC 1996). This is consistent with the forecasts of Schmalensee, Stoker, and Judson (1998) that also predict higher emissions that IPCC-92a through 2050 when using an environmental Kuznets curve specification. If our forecast were extended through to 2100, our emissions and stock calculation would be lower than those in Nordhaus (1998). Clearly, if CO_2 emissions do have an inverted U-shaped relationship to economic growth, the implications for climate change are profound.

IV.   Some empirical evidence on damages from climate change

We did not carry out any original research in this paper regarding the damages from rising GHG concentrations. Our findings, therefore, rely on the literature, specifically Nordhaus (1998) as previously explained. The main points that we stress are the following. First, very little is really known about likely damages, especially in the developing world. Second, even less is known about the likelihood of several hypothesized catastrophic events (such as runaway warming, due to feedbacks from the release of methane from frozen soils; or a collapse of ocean current systems; or a major melting of arctic icecaps; or a collapse of major ecosystems and the destruction of biodiversity). Third, the risks to the tropics exceed the risks to the temperate zones, most clearly in the effects on agriculture and on disease burdens. Unfortunately, serious

policy making will require a much firmer grasp of the likely damages from climate change than are yet available.

As previously explained, Nordhaus posits, then calibrates a damage function that is quadratic in temperature, making separate calibrations for major sub-regions of the world economy. He also distinguishes between non-catastrophic and catastrophic impacts, where the latter are measured as "insurance premiums" on the avoidance of catastrophic outcomes. Among the non-catastrophic damages, Nordhaus includes estimates of the costs of climate change on health, amenities (e.g. recreation), coastal flooding, and agricultural productivity.

The result of applying our projections of a 1.3-degree global temperature increase over 1990 levels by 2045 to the Nordhaus damage functions is shown in table 27.[17] We find that the U.S. economy is essentially unaffected by global warming, with a loss of just 0.05% of its own GDP. China is actually a beneficiary, because of presumed *improvements* in crop productivity. Europe is moderately affected, losing 1.54% of own GDP, mainly because of the presumed cost of sea level rising to coastal environments in Western Europe. The big losers, clearly, are the poorer countries, which generally experience major losses from agriculture, health, and rising sea levels. Africa, already the world's poorest region, is estimated to lose 3.75% of own GDP, and India is estimated to lose 3.35% of own GDP.

On the basis of the methodology developed in the companion theoretical paper, we can use the information in table 27 to obtain an estimate of the likely contributions of each region to the global damages and their share of these damages under a BAU scenario. The balance between the two will provide an indication of the direction of compensation flows. Column 3 is derived from the Nordhaus damage equation and translated into column 4. Column 4 is equivalent to the parameter λ_i described in section II. Column 5 is calculated from the historic and projected emissions and flow calculations described in sections III and IV. This column corresponds to the parameter σ_i described in section II. Recall that we defined $NTP_i = (\sigma_i - \lambda_i) WD$, where WD is total world damages. These transfers, expressed as percentage of GDP, are shown in the columns 6 and 7 of table 3. The U.S. and China are seen to contribute significantly to the global damages of which they suffer very little or benefit (in the case of China). India and Africa suffer a much bigger share of the damages than their contributions to the problem, and thus would receive compensation. Under a BAU scenario, this methodology results in flows from the

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17 Though not shown here, all regions are losers in the event of catastrophic impacts; the EU, India, and low-income countries are the hardest hit. These data on catastrophic impacts are enormously speculative and are mainly indicative of the considerations that should be examined in later work.

temperate zone to the tropical zone and, in general, from rich countries to poor ones. While these transfers do not reflect optimized damages or mitigation and adaptation efforts (defined as ΔY_i in section II); the BAU damages are likely to be high relative to the optimum. Given the vulnerability of the tropics to climate change however, it is likely that transfers in a context of optimal emissions would still flow from temperate to tropic and rich to poor.

We want to end this section by stressing once again the profound uncertainties that surround estimates such as these. All along we have stressed several weak links in the analysis, in the domains of atmospheric sciences, climatology, and economics. These are: (1) the links from economic development to carbon emissions, via the use of fossil fuels and land use changes; (2) the link from emissions to atmospheric carbon is hindered by the problem of "missing carbon" (that is, unidentified carbon sinks that appear to be limiting the rise of atmospheric carbon); (3) the link from atmospheric carbon to global and regional climate patterns, including temperature, precipitation, extreme events; and (4) the link from global and regional climate change to regional damages, in view of the possibilities technical innovation and societal adjustments to long-term changes in climatic conditions.

V.   Some policy implications

Even with the profound uncertainties, our empirical discussion suggests several general qualitative policy conclusions.

1. The non-Annex I countries are likely to increase significantly their rate of GHG emissions and the proportion of atmospheric GHG stocks for which they are responsible. This is because many developing countries are entering the range of GDP per capita at which emissions are a highly elastic function of GDP growth.
2. The Annex I countries are in the process of stabilizing or even reducing their levels of GHG emissions in the future, as part of an ongoing structural transformation from an industrial society to a service based, post-industrial society.
3. Along the global path of efficient mitigation, it is likely that the Annex I countries will have absolute declines in GHG emissions per capita, as they are already on a BAU trajectory of declining emissions per capita and an estimated negative elasticity of emissions per unit of GDP.
4. Along the global path of efficient mitigation, it is likely that the non-Annex I countries, and especially the developing countries, will have rising emissions per unit of GDP (an elasticity of emissions per GDP that is greater than or equal to 1.0). It may not be prudent to bind such countries to a baseline that preserves the ratio of

emissions to GDP, since economic development is associated with a rise in emissions-to-GDP ratio for countries below at least $8,000 per capita.

5. We do not have sufficient data about the elasticity of emissions per unit of GDP as economies continue to reach unprecedented levels of income per capita. Much will depend upon the realization of this parameter for the levels of emissions and GHG stocks in future years.

6. The stock of GHG emissions due to land use changes (especially deforestation) is unlikely to be highly significant for climate change in the long term. Of course, deforestation should be slowed or reversed for many other reasons, including more sustainable and efficient land use patterns, the preservation of biodiversity, and the preservation of social habitats for indigenous populations.

7. It appears that Annex I countries will be disproportionately responsible for the projected increase in GHG atmospheric concentrations, while bearing few of the costs. On the other hand, Annex II countries, by and large, bear heavier costs of climate change and have a disproportionately lower role in the increase of GHGs.

8. The implication of this finding is that compensation for climatic damages will flow from rich to poor countries. According to our crude estimates, these transfer payments may be as much as 1.35 percent of world GDP by 2045.

9. A major exception to this conclusion is China. China bears few projected costs of climate change, but is a projected large contributor to GHG emissions. This would also call for compensation from China to other developing countries on the BAU path.

10. The projected non-catastrophic damages in the Nordhaus damage functions are too low to justify a major mitigation effort as a proportion of current worldwide GDP. Since these damage functions are very crude, and much depends on the real magnitudes of damages from climate change, much more work is needed, on a high-priority basis, to assess possible damages, and thereby to calibrate better the appropriate levels of societal response.

11. The projected non-catastrophic damages in the Nordhaus damage functions are too low to justify a major mitigation effort as a proportion of current worldwide GDP. Since these damage functions are very crude, and much depends on the real magnitudes of damages from climate change, much more work is needed, on a high priority basis, to assess possible damages, and thereby to calibrate better the appropriate levels of societal response.

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VII.   Tables and Figures

Figure 1 CO₂ Emissions per Capita in Selected Countries

CO2 emissions per Capita USA 1960- 94 (million tons of C)

CO2 emissions per capita UK 1960-94 (million tons of C)

CO2 emissions per capita Japan 1960-94 (million tons of C)

Figure 1 CO₂ Emissions per Capita in Selected Countries

CO2 emissions per capita France 1960-94 (million tons of C)

CO2 emissions per capita Netherlands 1960-94 (million tons of C)

CO2 per Capita Canada 1960-94 (million tons of C)
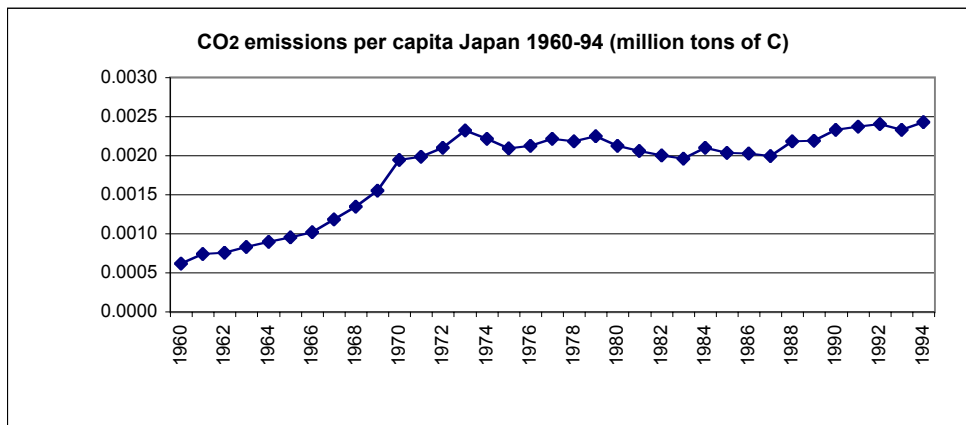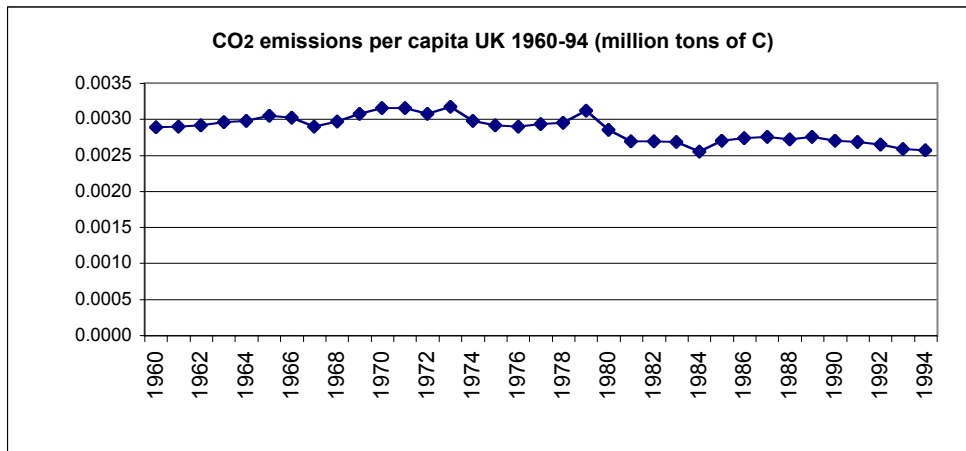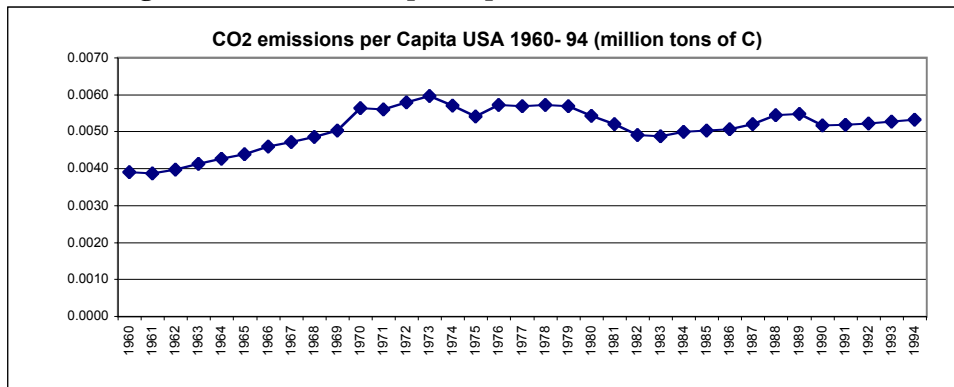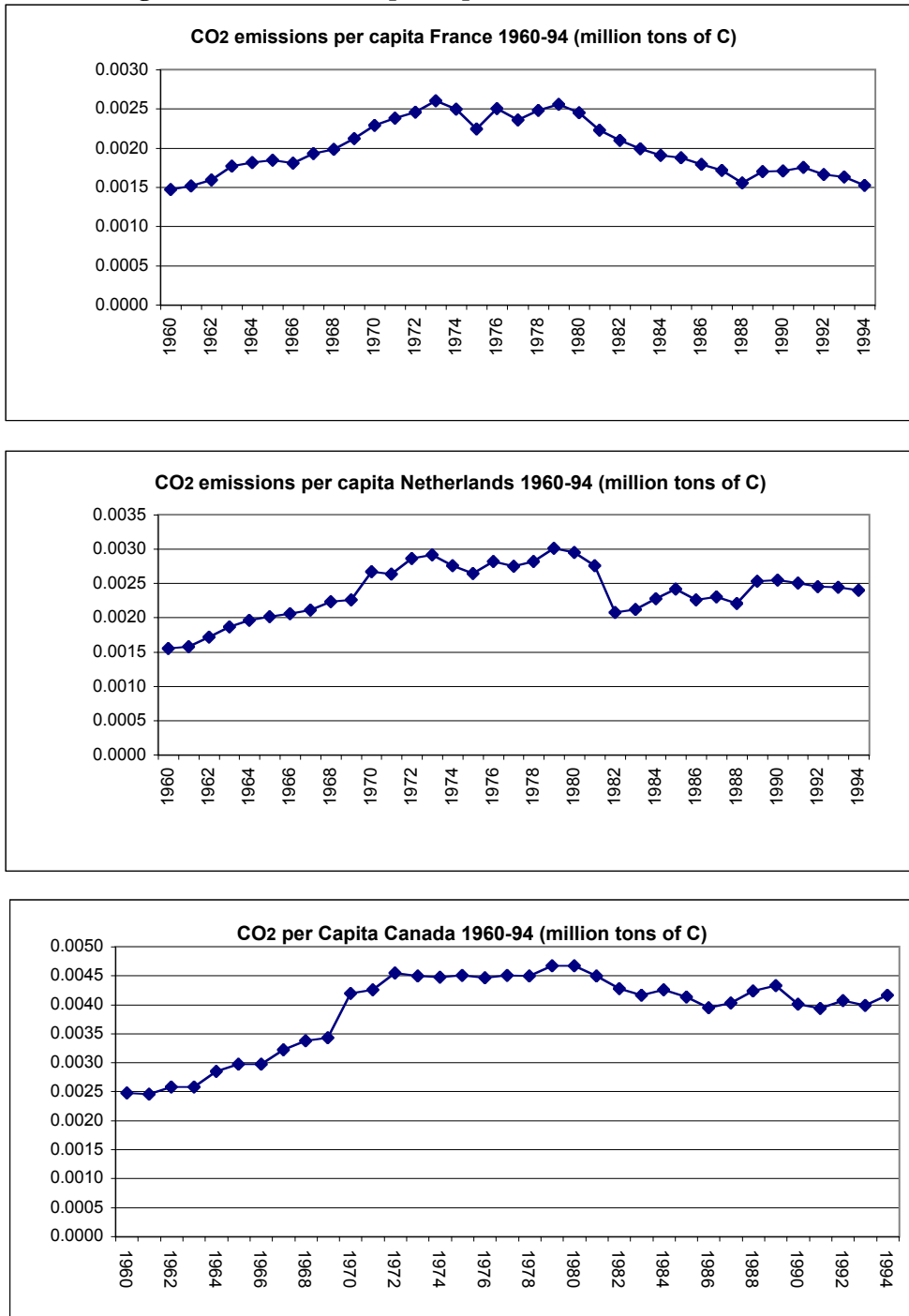
Figure 2 CO₂ Emission Flows from Fossil Fuels 1860-1996 (billion tons of C)

1
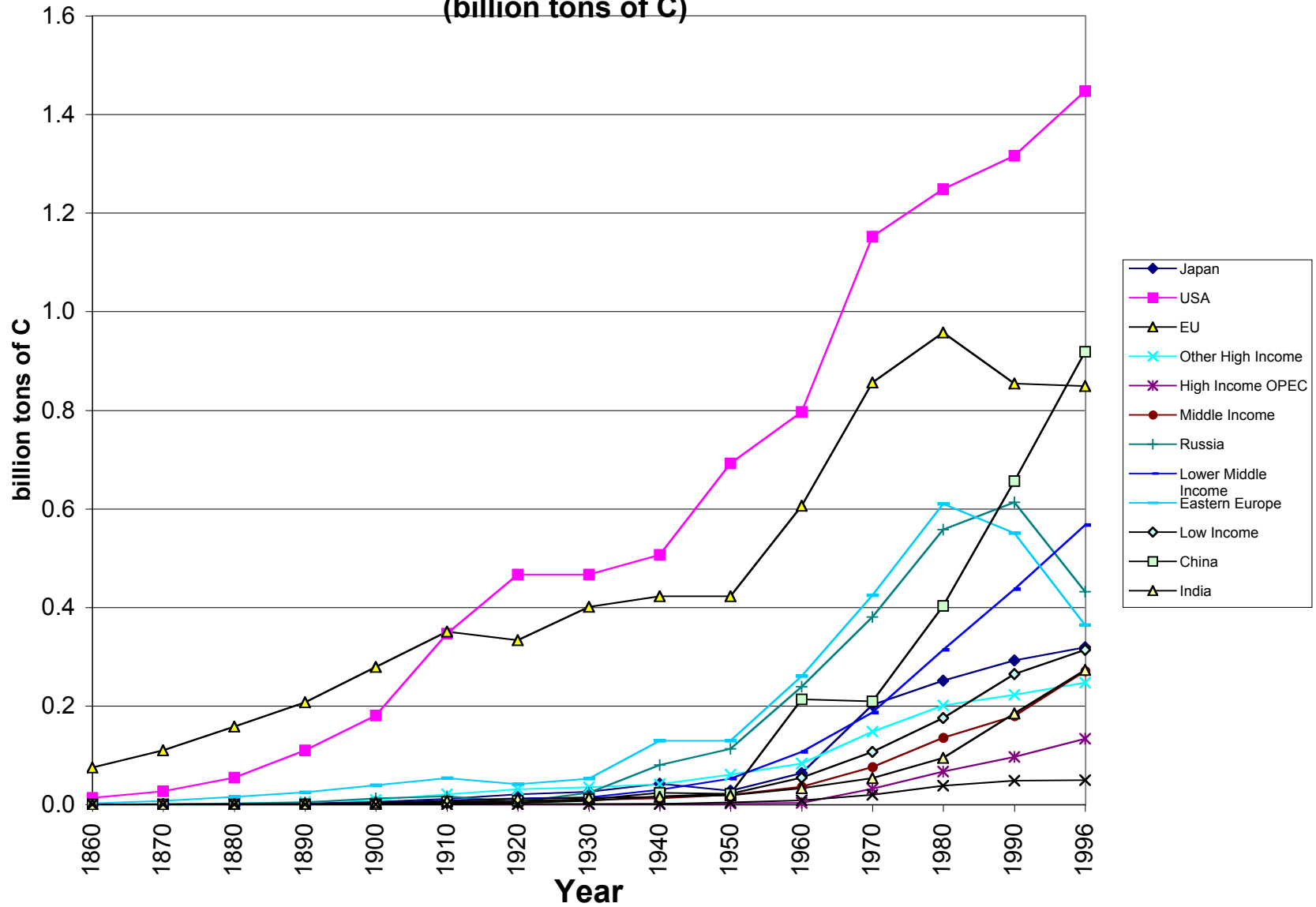
Figure 3 Stock of CO₂ from Fossil Fuels 1860-1996 (billion tons of C)

1
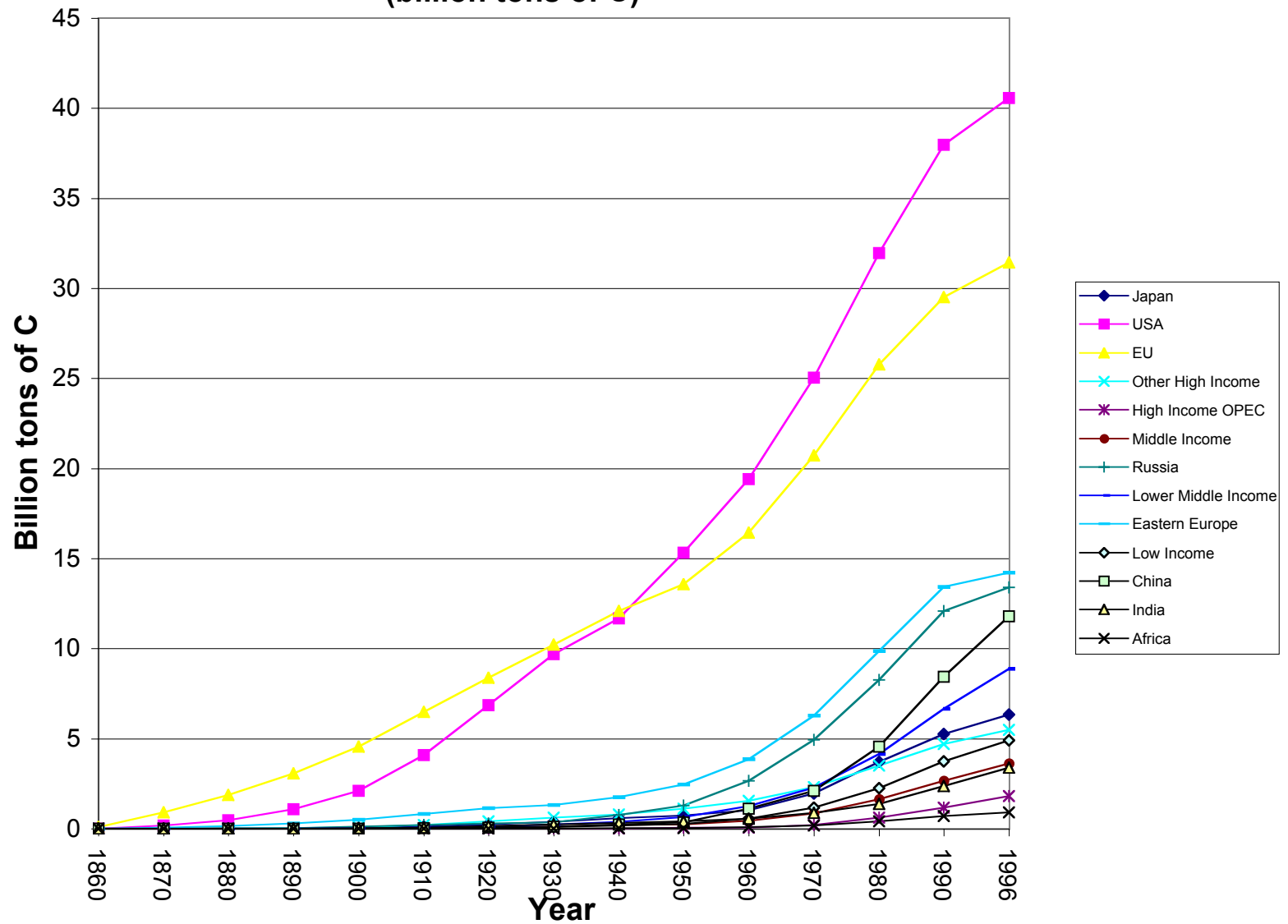
**Figure 4 Estimated CO₂ Emissions from Land Use Change 1860-1990
(billion tons of C)**
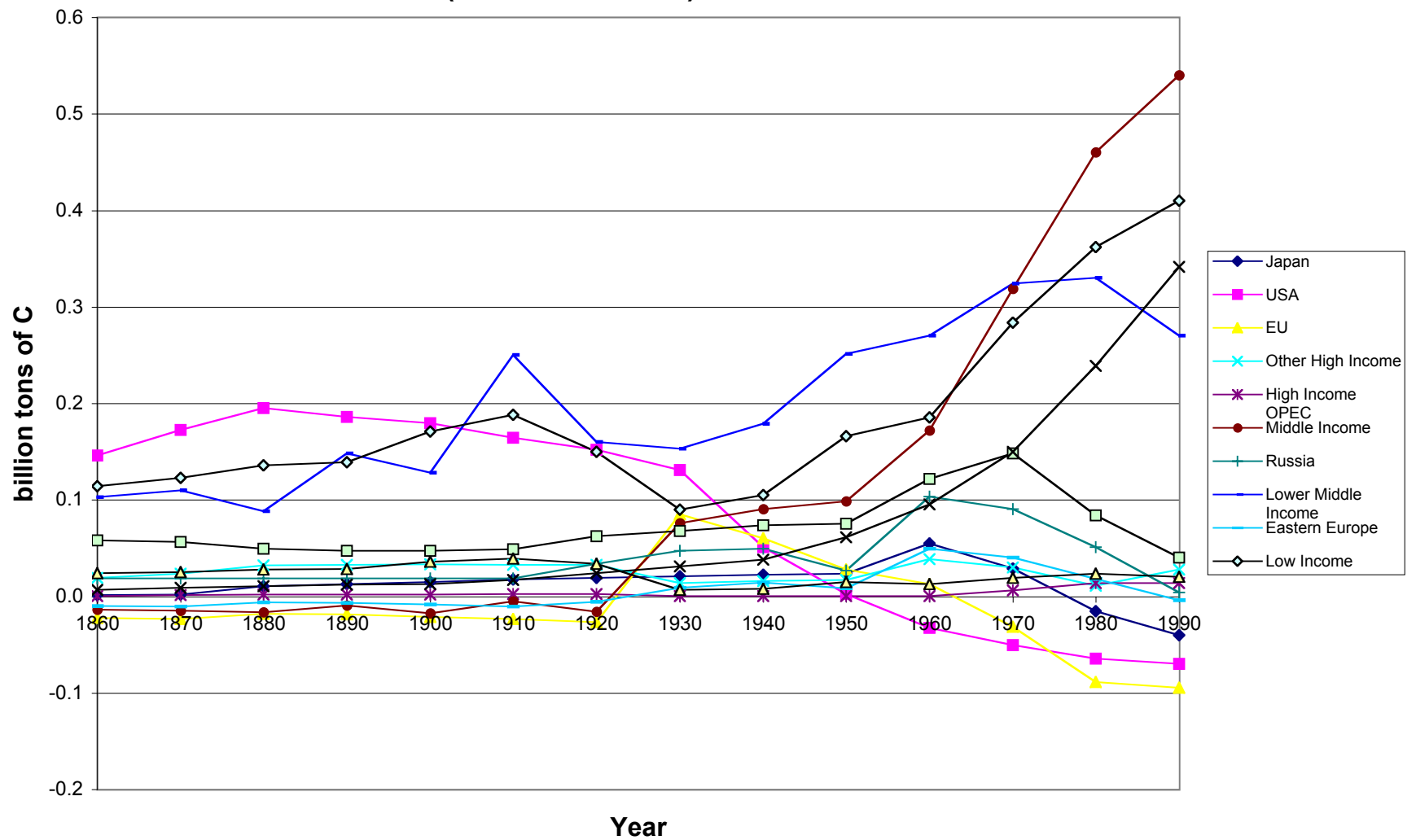
Figure 5 Stock of CO₂ from Land Use Change 1860-1990 (billion tons of C)
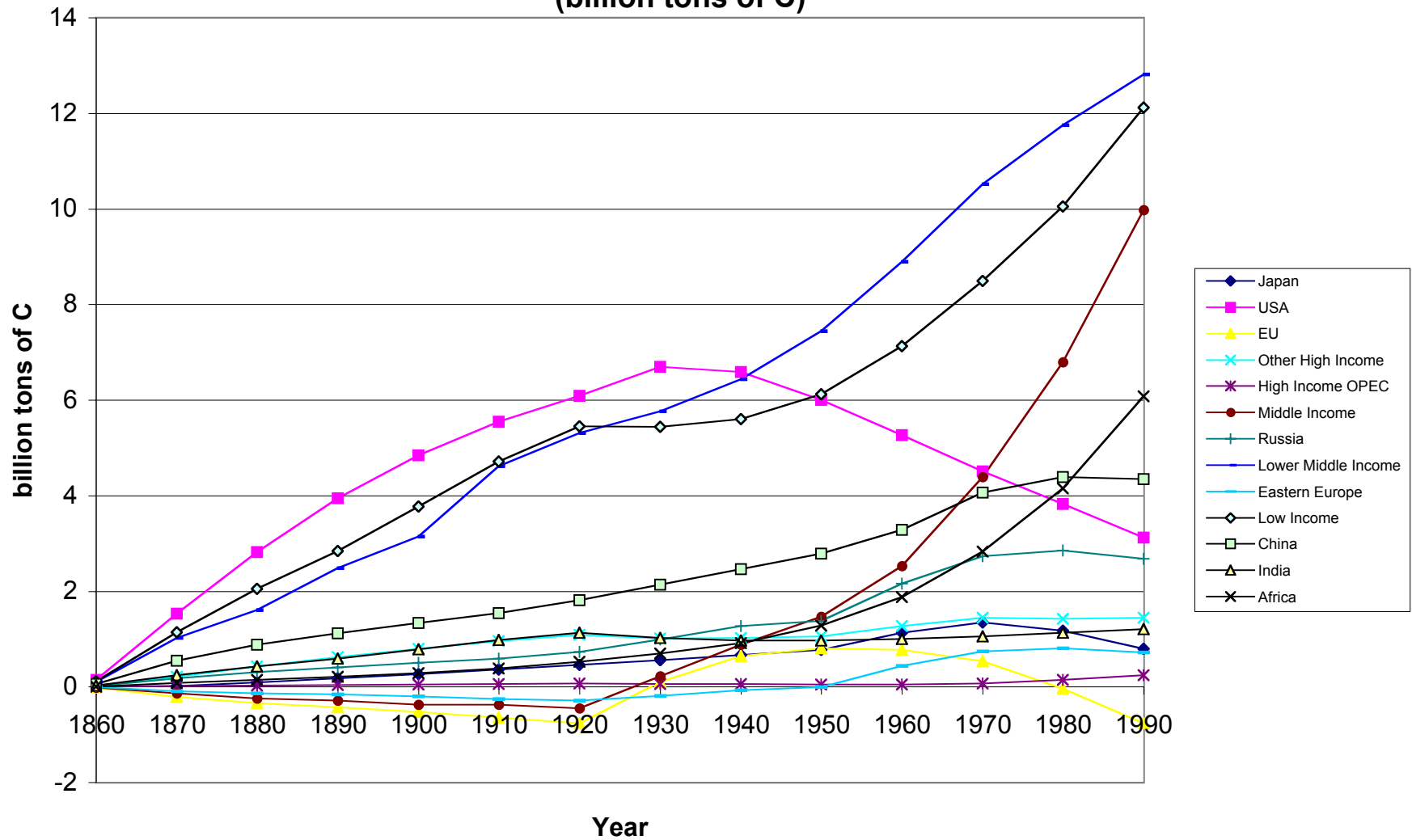
**Figure 6 Projected Flows of CO$_2$ Emissions from Fossil Fuels 1996-2050
(billion tons of C)**

Legend:
- Japan
- USA
- EU
- Other High Income
- High Income OPEC
- Middle Income
- Russia
- Lower Middle Income
- Eastern Europe
- Low Income
- China
- India
- Africa

Y-axis: billion tons of C

X-axis: Year
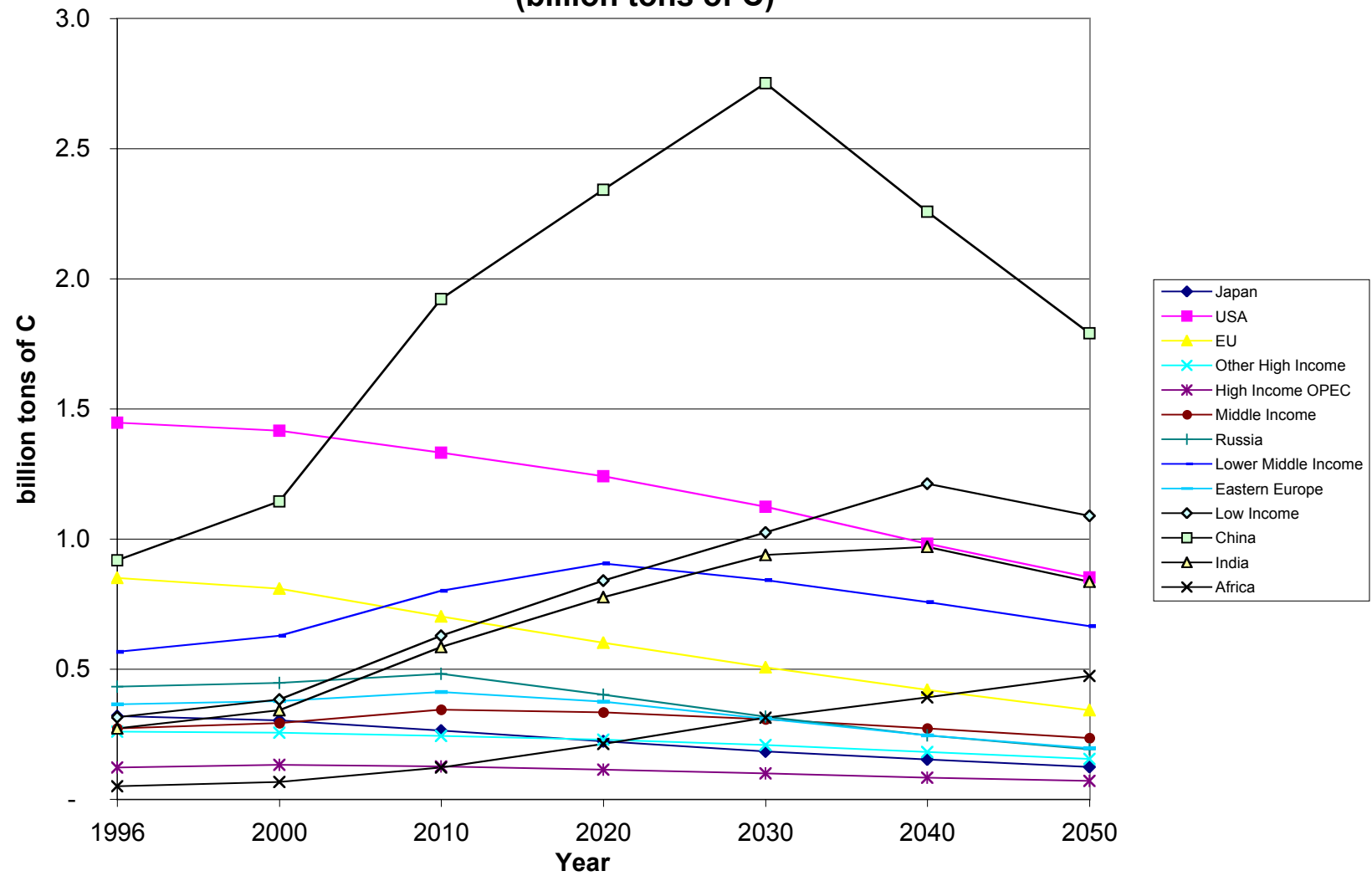
Figure 7 Projected Stock of CO2 from Fossil Fuels 1996-2050 (billion tons of C)
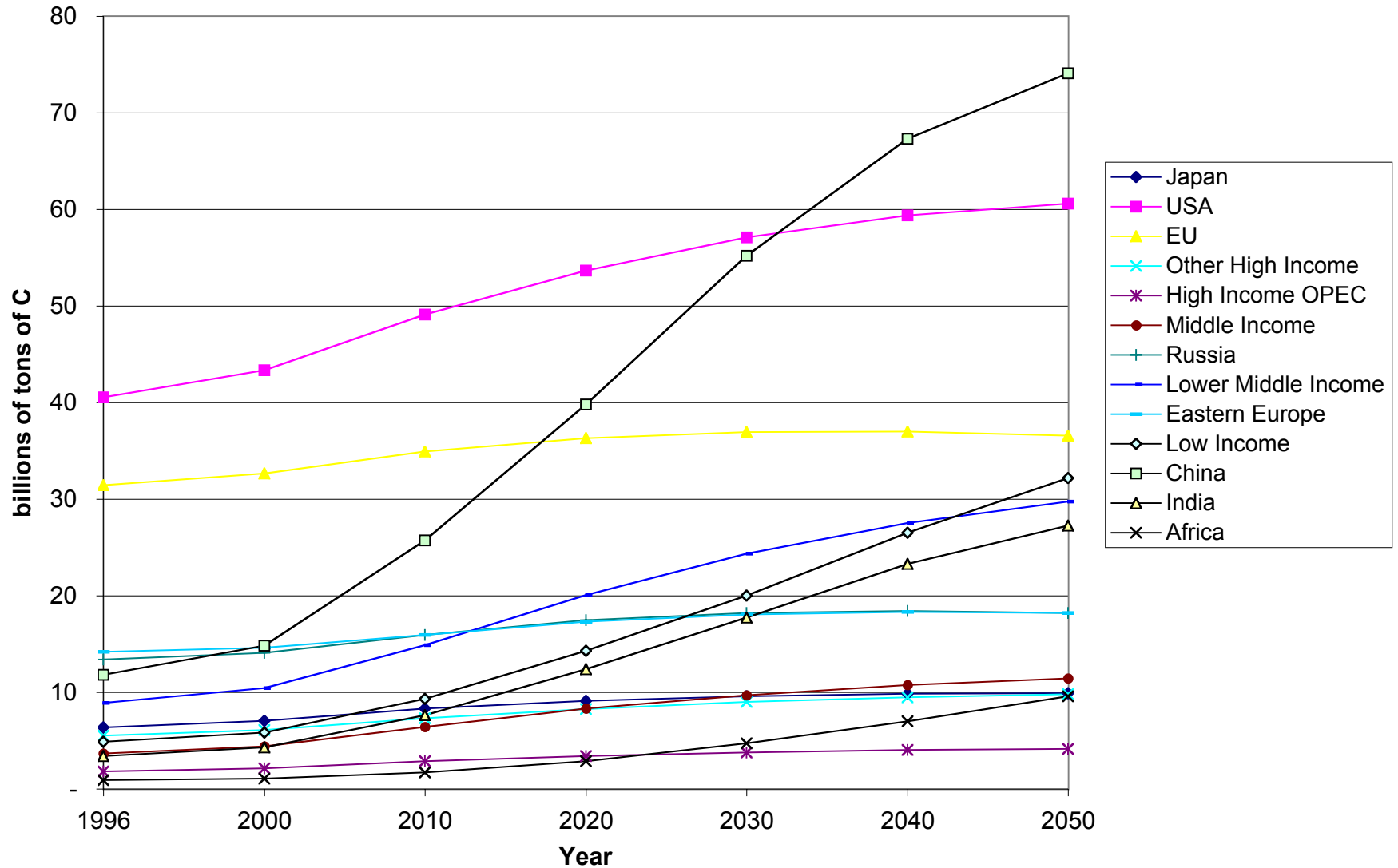
Figure 8 Projected Flow of CO2 from Land Use Change 1990-2050 (billion tons of C)

Legend:
- Japan
- USA
- EU
- Other High Income
- High Income OPEC
- Middle Income
- Russia
- Lower Middle Income
- Eastern Europe
- Low Income
- China
- India
- Africa

Y-axis: billion tons of C (0.6, 0.5, 0.4, 0.3, 0.2, 0.1, -, (0.1), (0.2))

X-axis: Year (1990, 2000, 2010, 2020, 2030, 2040, 2050)
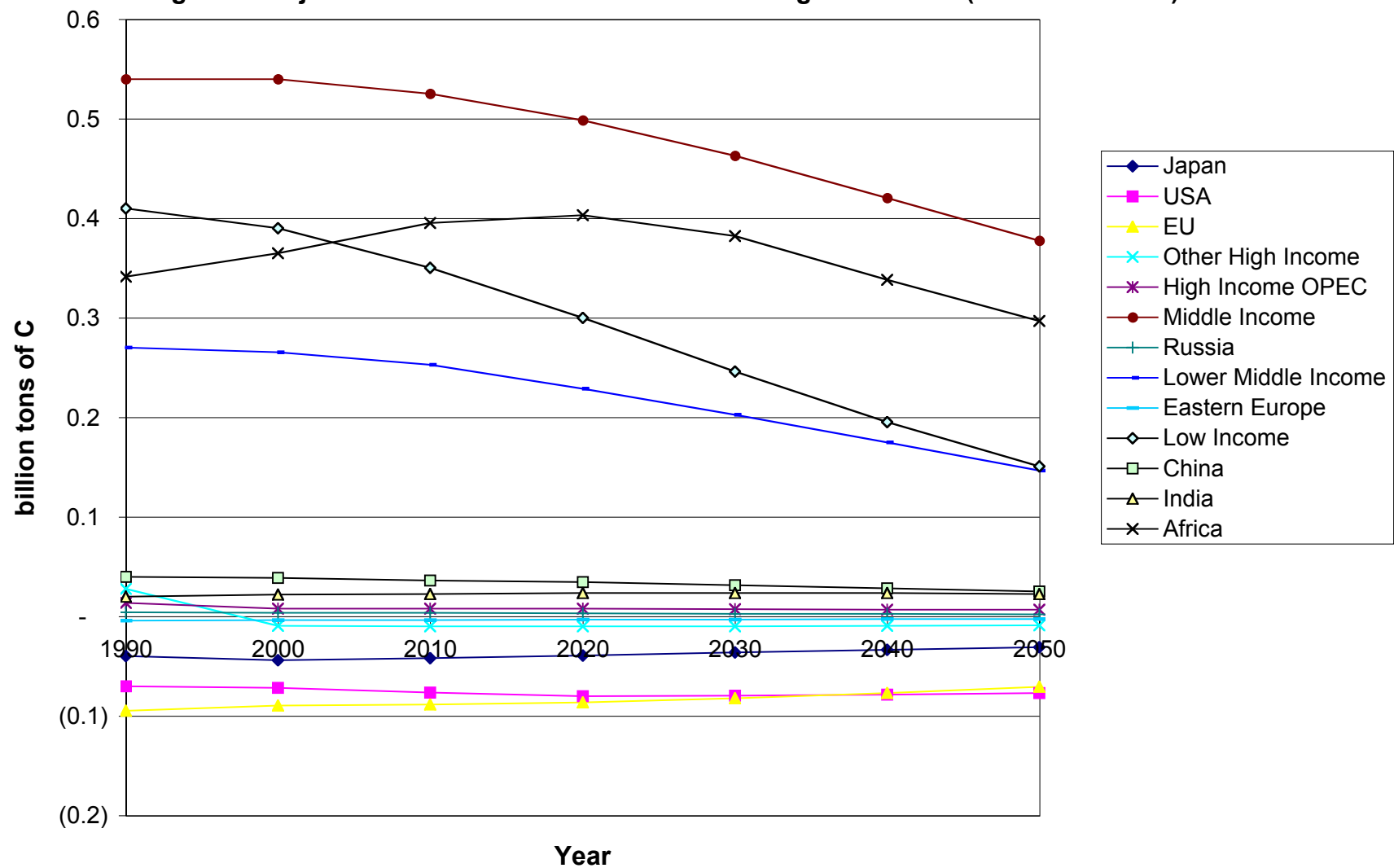
Figure 9 Projected Stock of CO$_2$ from Land Use Change 1990-2050 (billion tons of C)
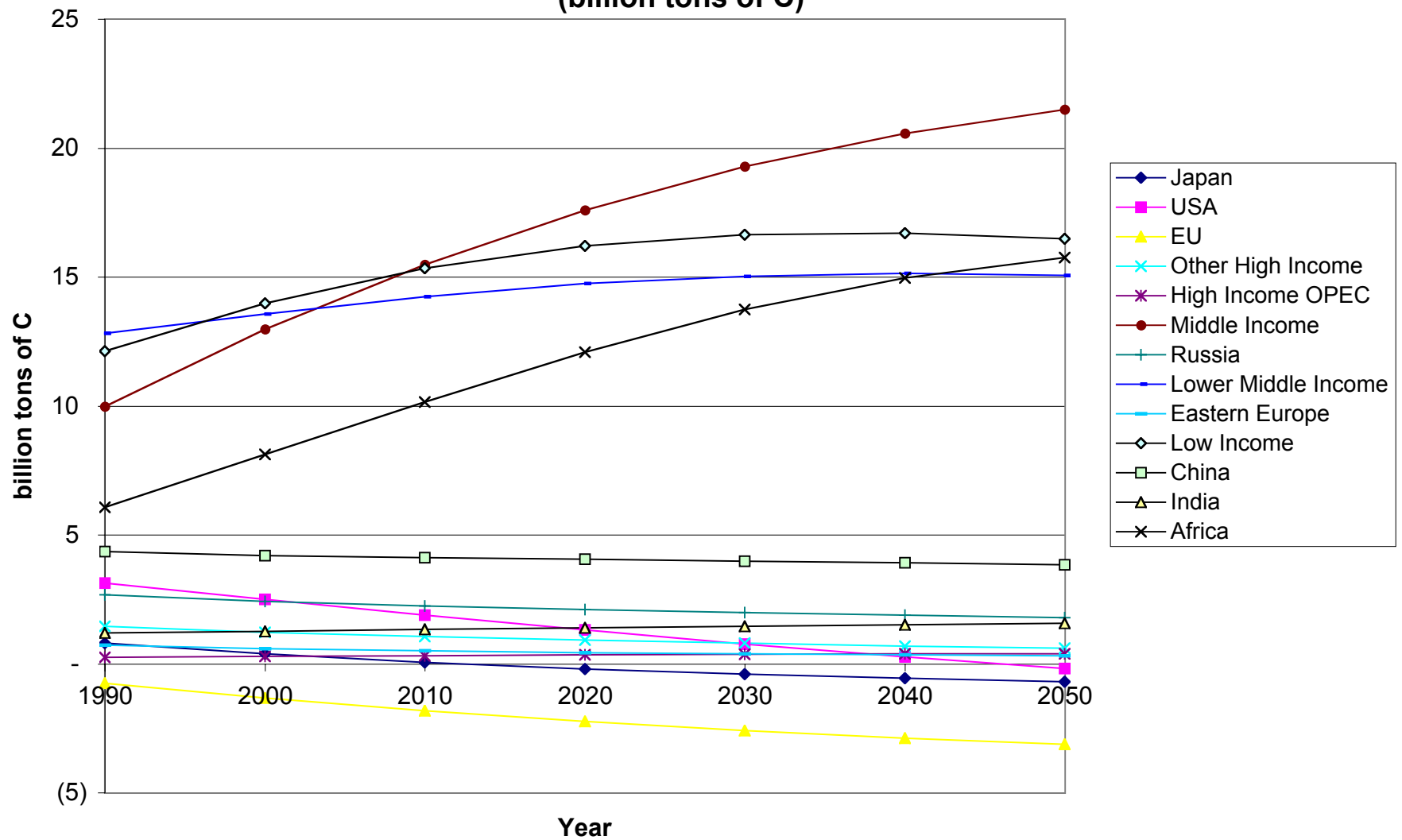
Figure 10 Historic and Projected Flows of CO₂ from Fossil Fuels 1860-2050 (billion tons of C)
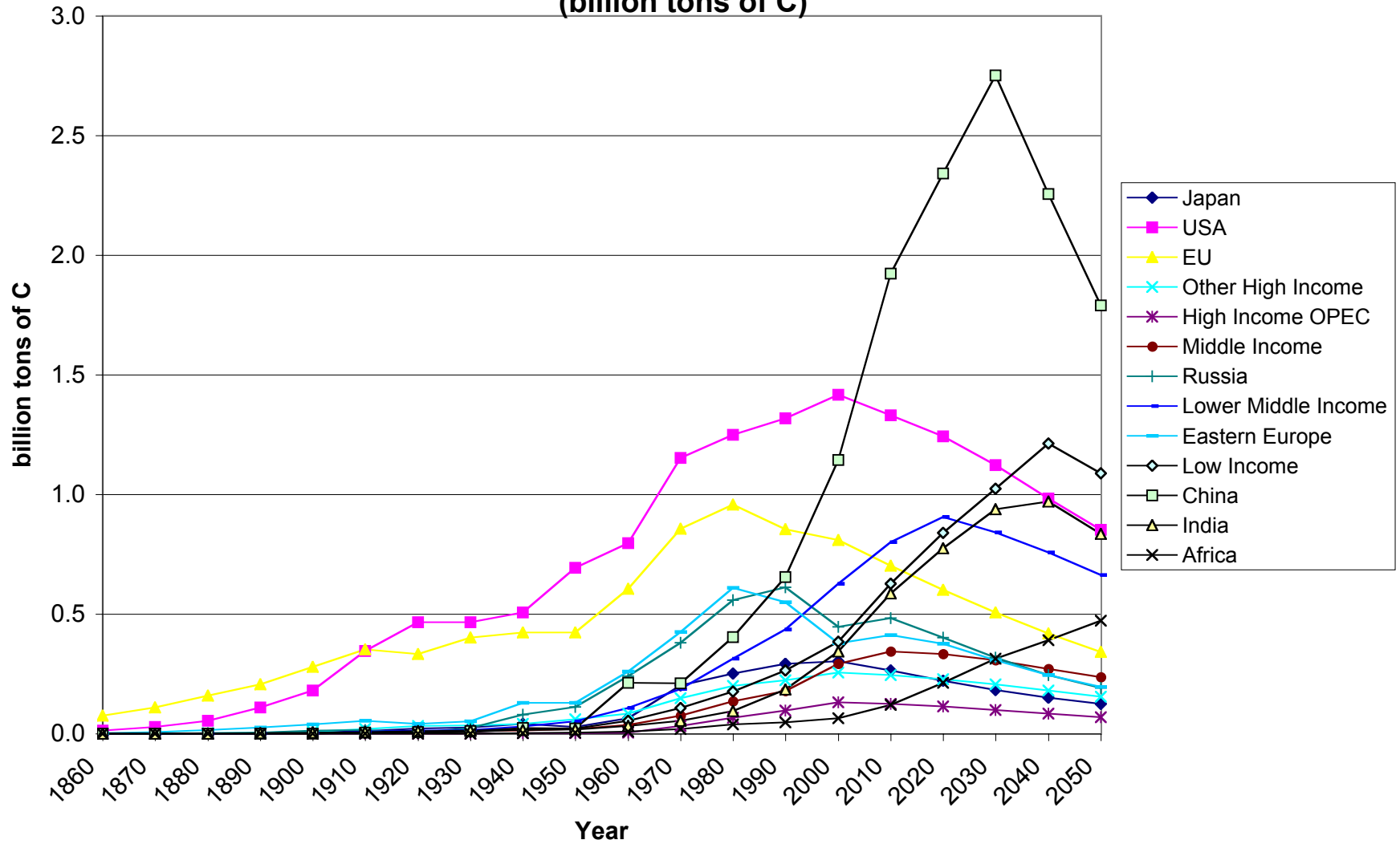
Figure 11 Historic and Projected Stocks of CO2 from Fossil Fuels 1860-2050 (billion tons of C)
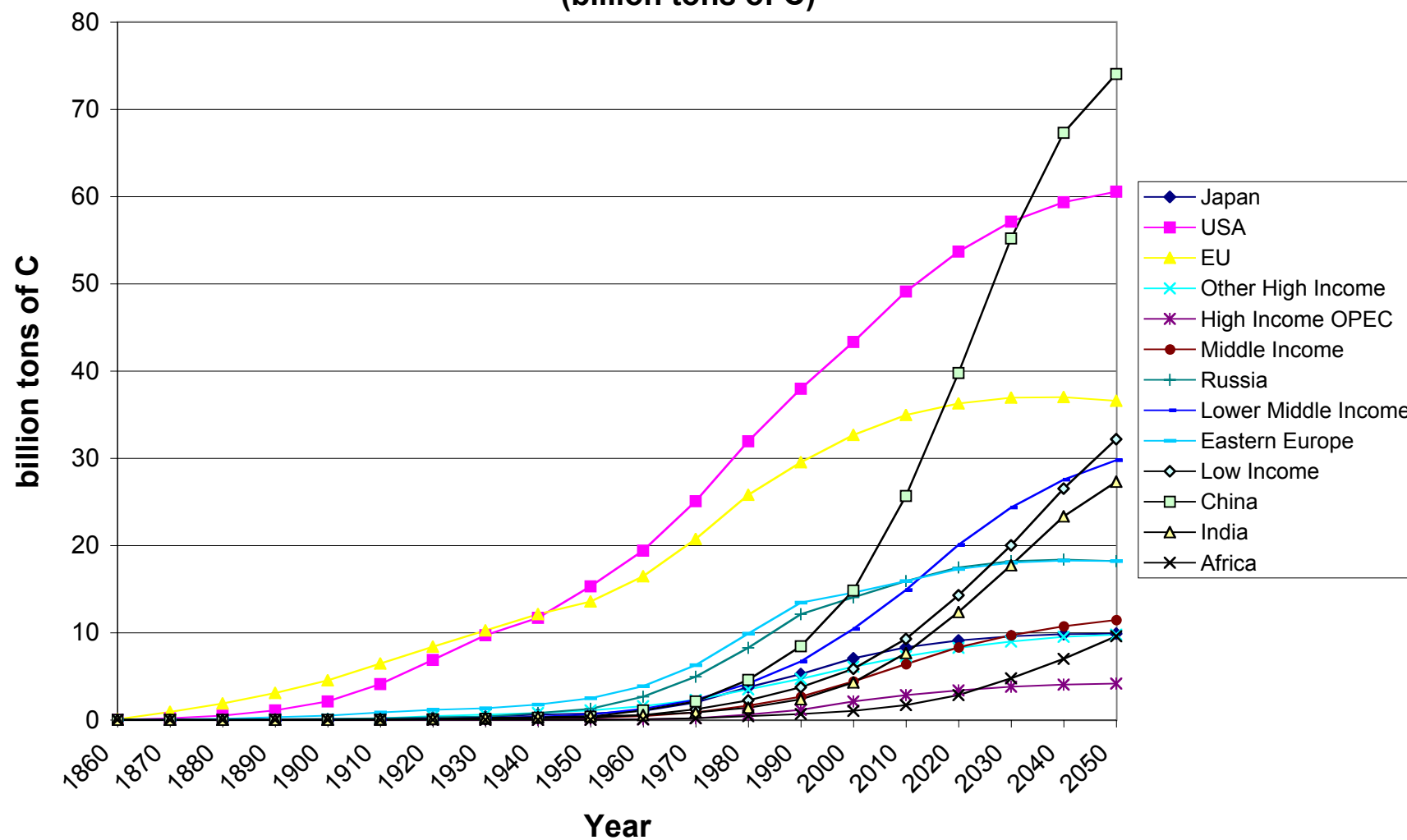
Figure 12 Historic and Projected Flows of CO₂ from Land Use Change 1860-2050 (billion tons of C)
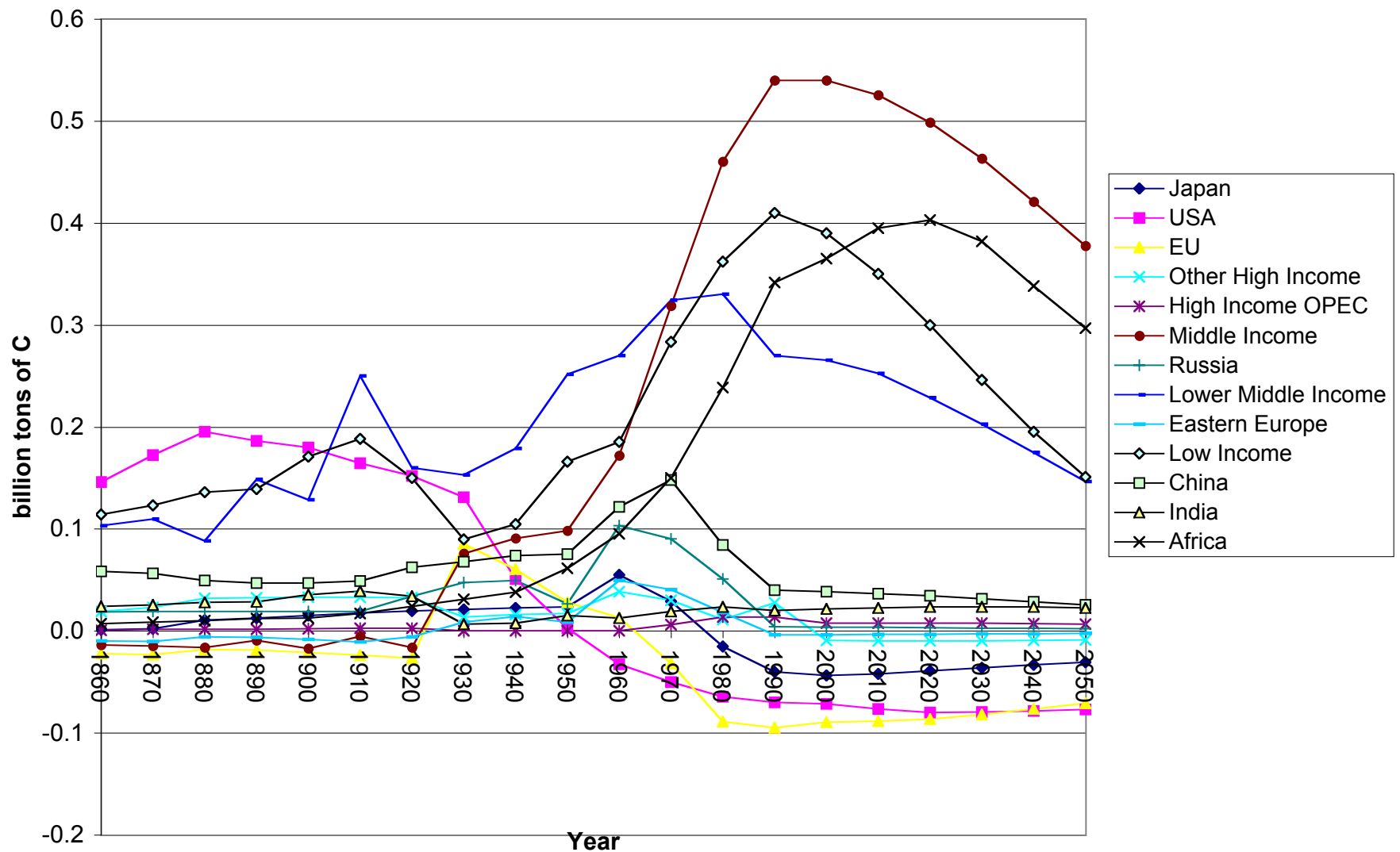
Figure 13 Historic and Projected Stock of CO2 from Land Use Change 1860-2050 (billion tons of C)

Legend:
- Japan
- USA
- EU
- Other High Income
- High Income OPEC
- Middle Income
- Russia
- Lower Middle Income
- Eastern Europe
- Low Income
- China
- India
- Africa

Y-axis: billion tons of C

X-axis: Year
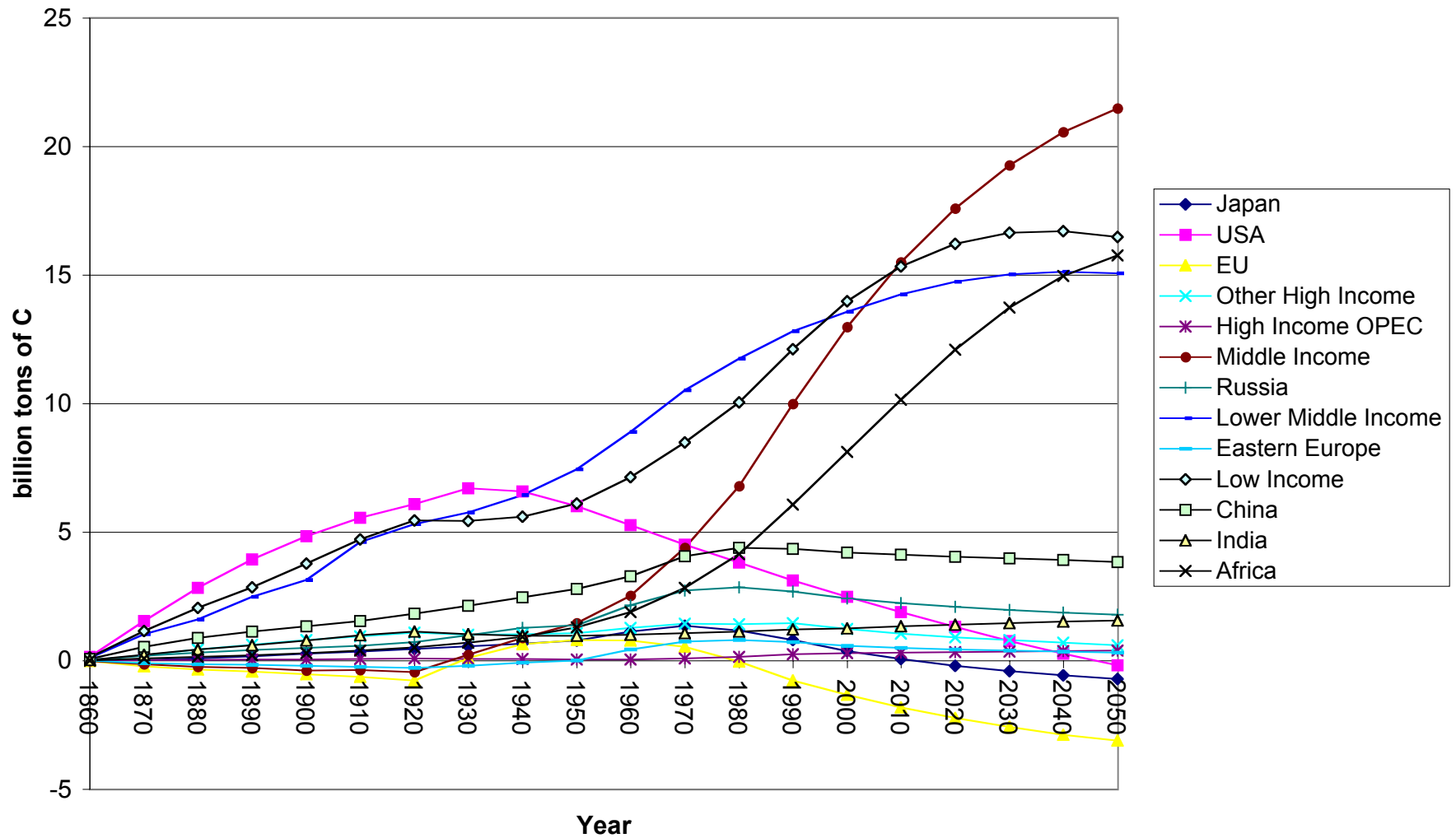
Figure 14 Historic and Projected Flow of CO$_2$ from Fossil Fuels & Land Use Change 1860-2050 (billion tons of C)
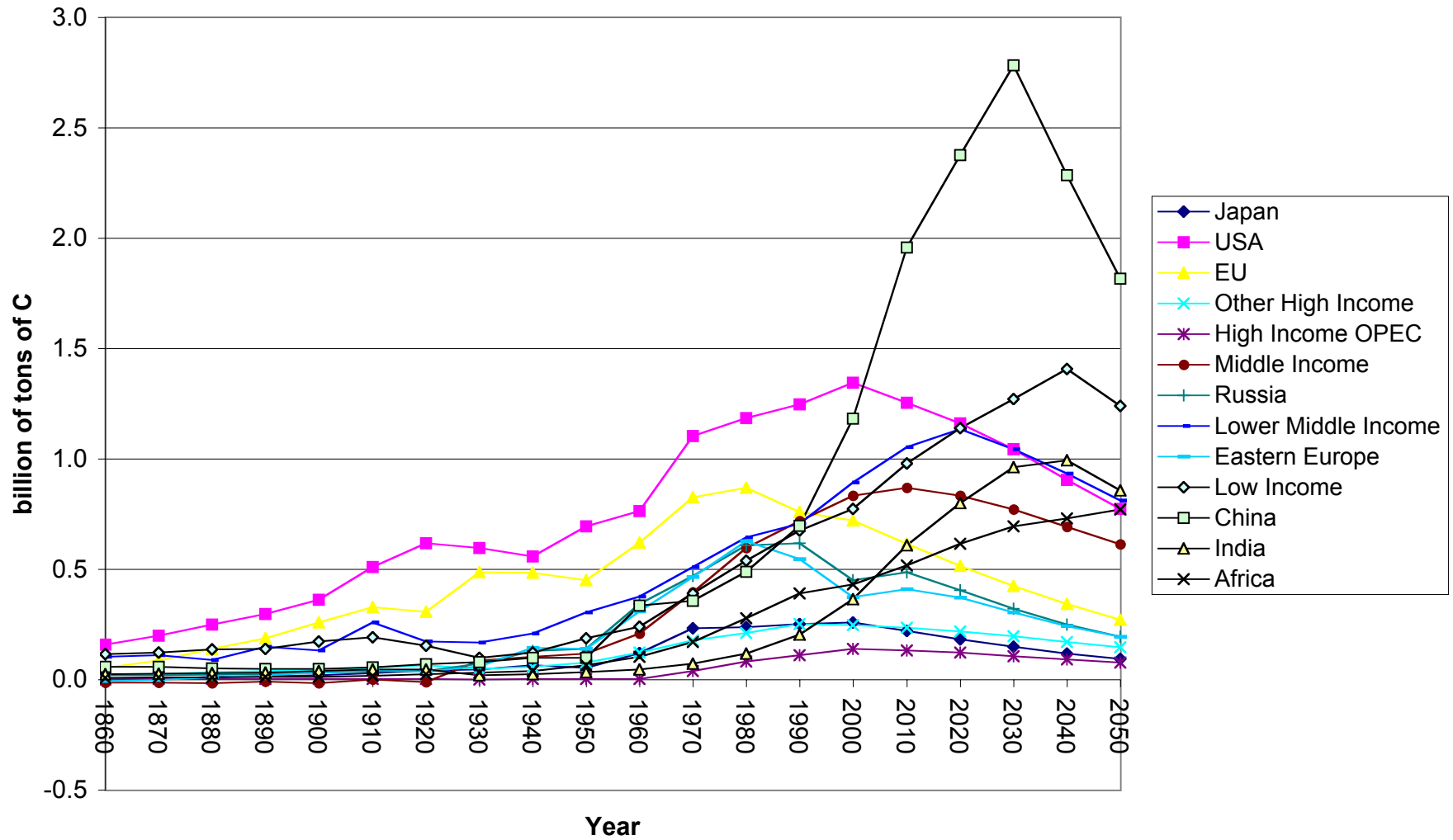
Figure 15 Historic and Projected Stock of CO$_2$ from Fossil Fuels and Land Use 1860-2050 (billion tons of C)
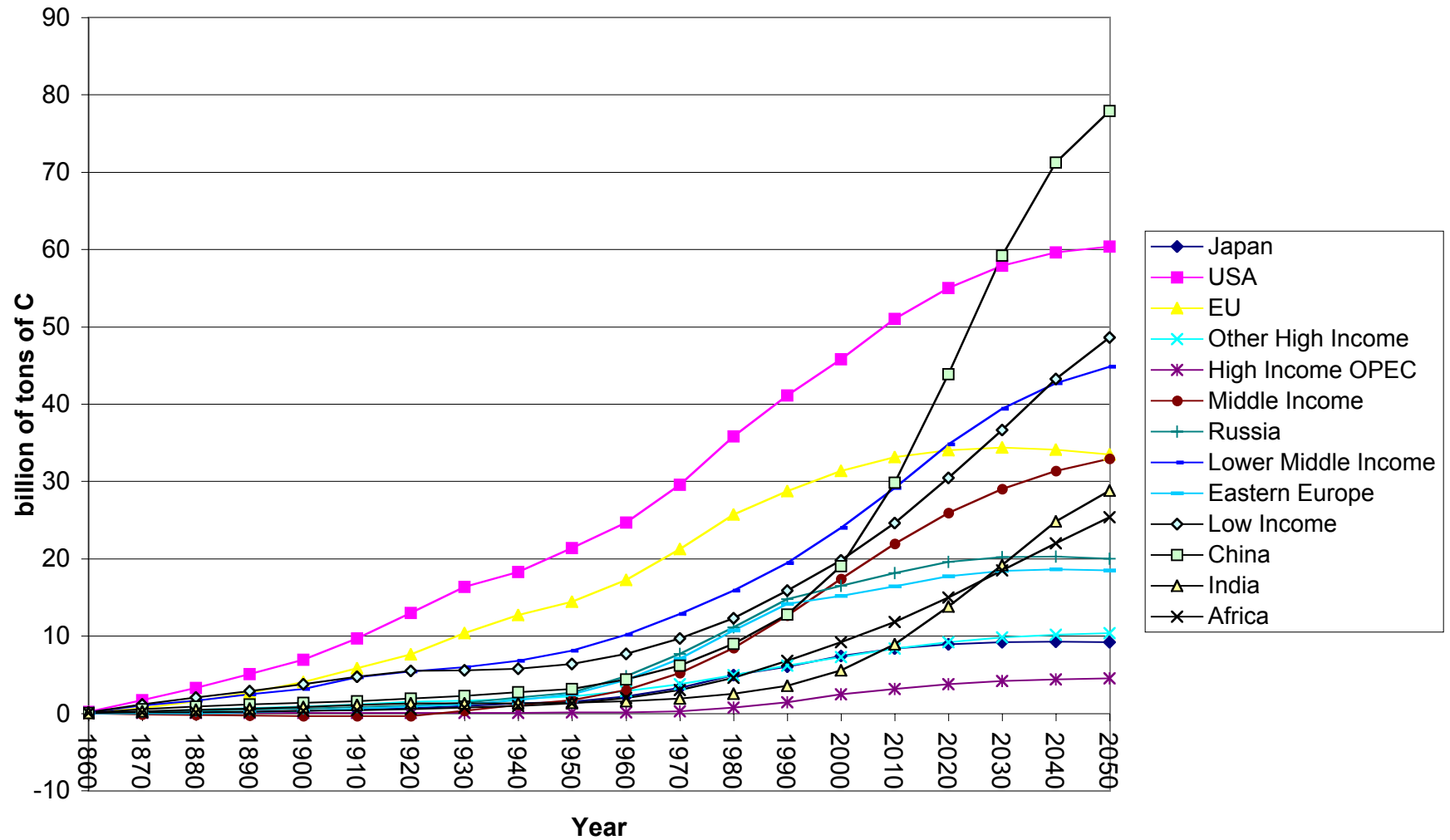
Figure 16 CO2 Emissions- Comparison to the Nordhaus RICE model (1995-2045)
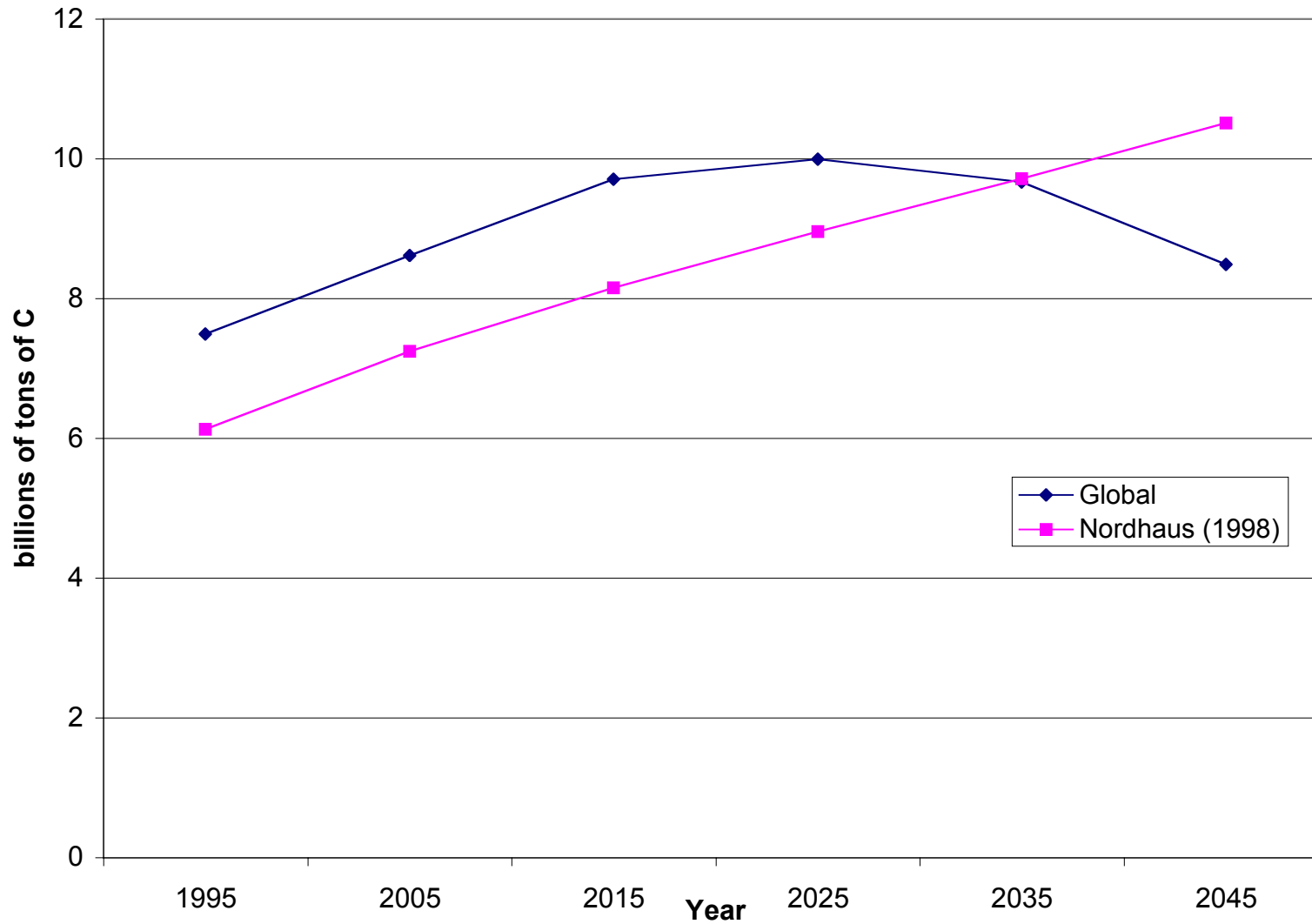
Table 1 <u>Summary of Data Used in Econometric Analysis</u>

Data Available	Annex I	Non-Annex I	Temperate	Non-Temperate	World
<u>YEARS</u>					
Carbon Emissions from Fossil Fuels (annual)	1960-92	1960-92	1960-92	1960-92	1960-92
Carbon Emissions from Land Use Change	1991	1991	1991	1991	1991
<u>COUNTRIES</u>					
General Information (Population, GDP, etc.)	33	97	43	87	130
Carbon Emissions from Fuel Combustion	42	113	65	90	155
Carbon Emissions for Land Use Change	30	91	42	79	121
<u>OBSERVATIONS</u>					
Fossil Fuel Combustion Regressions (No Price)	1102	3749	1630	3221	4851
Fossil Fuel Combustion Regressions (With Price)	344	458	423	379	802
Land Use Change Regressions (Cross Section)	30	91	42	79	121

Table 2 Low Middle and High Income Countries Summary Information

World Totals 1994	Low income	Middle Income	High Income	World
Population (billion)	1.81	2.78	0.85	5.43
PPP GDP (trillion 87 int'l $)	1.72	8.62	12.91	23.25
Real GDP (trillion 87 us$)	0.73	3.26	13.75	17.74
Combustion emissions (billion metric tons C)	0.36	2.33	2.61	5.30
Land-use change emissions (billion metric tons C)	0.42	1.02	-0.08	1.36
Total anthropogenic CO_2 emissions (billion metric tons C)	0.78	3.36	2.52	6.66
Share of total emissions due to land use change (%)	53.89	30.44	-3.26	20.41

Per Capita 1994	Low income	Middle Income	High Income	World
PPP GDP (87 int'l$/capita)	948	3105	15239	4278
Real GDP (87 $us/capita)	402	1175	16221	3263
Combustion emissions (metric tons C/capita)	0.20	0.84	3.08	0.98
Land use change emissions (metric tons C/capita)	0.23	0.37	-0.10	0.25
Total Anthropogenic emissions (metric tons C/capita)	0.43	1.21	2.98	1.23

Table 3 Low Middle and High Income Countries Summary Information

Per unit GDP 1994	Low income	Middle Income	High Income	World
Combustion emissions (metric tons C per millions of 1987 PPP $)	206	234	141	228
Land use change emissions (metric tons C per millions of 1987 PPP $)	255	131	-20	100
Total Antropogenic emissions (metric tons C per millions of 1987 PPP $)	454	389	196	303

World Shares 1994 (%)	Low income	Middle Income	High Income	World
Population	33.33	51.07	15.59	100.00
PPP GDP	7.38	37.07	55.54	100.00
Real GDP	4.11	18.39	77.50	100.00
Combustion emissions	6.78	44.03	49.18	100.00
Land-use change emissions	30.91	75.14	-6.05	100.00
Total anthropogenic CO2 emissions	11.71	50.38	37.91	100.00

Annual Growth Rates 1990-1994 (%)	Low income	Middle Income	High Income	World
Population	2.20	1.46	0.76	1.55
PPP GDP	3.95	5.38	1.74	2.62
Real GDP	3.87	3.79	1.76	1.84
Combustion emissions	5.94	5.01	1.51	1.70

Table 4 Temperate and Tropical Countries Summary Information

World Totals 1994	Temperate (65 countries)	Non Temperate (90 countries)	Total World Sample (155 countries)
Population (billion)	2.65	2.78	5.43
PPP GDP (trillion 87 int'l $)	17.76	5.49	23.25
Real GDP (trillion 87 us$)	15.25	2.48	17.74
Combustion emissions (billion metric tons C)	4.22	1.08	5.30
Land-use change emissions (billion metric tons C)	0.05	1.31	1.36
Total anthropogenic CO_2 emissions (billion metric tons C)	4.28	2.38	6.66
Share of total emissions due to land use change (%)	1.20	54.86	20.41

Per Capita 1994	Temperate (65 countries)	Non Temperate (90 countries)	Total World Sample (155 countries)
PPP GDP (87 int'l$/capita)	6693	1974	4278
Real GDP (87 $us/capita)	5749	893	3263
Combustion emissions (metric tons C/capita)	1.59	0.39	0.98
Land use change emissions (metric tons C/capita)	0.02	0.47	0.25
Total Anthropogenic emissions (metric tons C/capita)	1.61	0.86	1.23

Table 5 Temperate and Tropical Countries Summary Information

Per unit GDP 1994	Temperate (65 countries)	Non Temperate (90 countries)	Total World Sample (155 countries)
Combustion emissions (metric tons C per millions of 1987 PPP $)	238	196	228
Land use change emissions (metric tons C per millions of 1987 PPP $)	6	276	100
Total Antropogenic emissions (metric tons C per millions of 1987 PPP $)	218	462	303

World Shares 1994 (%)	Temperate (65 countries)	Non Temperate (90 countries)	Total World Sample (155 countries)
Population	48.82	51.18	100.00
PPP GDP	76.38	23.62	100.00
Real GDP	86.00	14.00	100.00
Combustion emissions	79.69	20.31	100.00
Land-use change emissions	3.76	96.24	100.00
Total anthropogenic CO2 emissions	64.19	35.81	100.00

Annual Growth Rates 1990-1994 (%)	Temperate (65 countries)	Non Temperate (90 countries)	Total World Sample (155 countries)
Population	0.94	2.17	1.55
PPP GDP	2.32	3.63	2.62
Real GDP	1.57	3.61	1.84
Combustion emissions	0.68	6.62	1.70

Table 6 Annex 1 and Non-Annex 1 Countries Summary Information

World Totals 1994	Annex 1 (42 countries)	Non-Annex 1 (113 countries)	Total World Sample (155 countries)
Population (billion)	1.27	4.17	5.43
PPP GDP (trillion 87 int'l $)	14.64	8.62	23.26
Real GDP (trillion 87 us$)	14.47	3.26	17.74
Combustion emissions (billion metric tons C)	3.33	1.97	5.30
Land-use change emissions (billion metric tons C)	-0.05	1.41	1.36
Total anthropogenic CO_2 emissions (billion metric tons C)	3.28	3.38	6.66
Share of total emissions due to land use change (%)	-1.49	41.64	20.41

Per Capita 1994	Annex 1 (42 countries)	Non-Annex 1 (113 countries)	Total World Sample (155 countries)
PPP GDP (87 int'l$/capita)	11531	2069	4279
Real GDP (87 $us/capita)	11399	784	3263
Combustion emissions (metric tons C/capita)	2.62	0.47	0.98
Land use change emissions (metric tons C/capita)	-0.04	0.34	0.25
Total Anthropogenic emissions (metric tons C/capita)	2.58	0.81	1.23

Table 7 Annex 1 and Non-Annex 1 Countries Summary Information

Per unit GDP 1994	Annex 1 (36 countries)	Non-Annex 1 (130 countries)	Total World Sample (166 countries)
Combustion emissions (metric tons C per millions of 1987 PPP $)	228	229	228
Land use change emissions (metric tons C per millions of 1987 PPP $)	-9	180	100
Total Antropogenic emissions (metric tons C per millions of 1987 PPP $)	162	405	303

World Shares 1994 (%)	Annex 1 (42 countries)	Non-Annex 1 (113 countries)	Total World Sample (155 countries)
Population	23.36	76.64	100.00
PPP GDP	62.95	37.05	100.00
Real GDP	81.60	18.40	100.00
Combustion emissions	62.76	37.24	100.00
Land-use change emissions	-3.59	103.59	100.00
Total anthropogenic CO2 emissions	49.22	50.78	100.00

Annual Growth Rates 1990-1994 (%)	Annex 1 (42 countries)	Non-Annex 1 (113 countries)	Total World Sample (155 countries)
Population	0.58	1.87	1.55
PPP GDP	0.86	6.22	2.62
Real GDP	1.21	5.02	1.84
Combustion emissions	-0.64	6.85	1.70

Table 8 Key Countries Summary Information

Country Totals 1994	Brazil	China	India	Indonesia	Mexico	South Africa
Population (billion)	0.16	1.19	0.91	0.19	0.09	0.04
PPP GDP (trillion 87 int'l $)	0.71	2.53	1.00	0.44	0.57	0.20
Real GDP (trillion 87 us$)	0.32	0.52	0.37	0.13	0.17	0.09
Combustion emissions (billion metric tons C)	0.06	0.83	0.24	0.07	0.10	0.09
Land-use change emissions (billion metric tons C)	0.32	-0.01	-0.01	0.14	0.07	0.00
Total anthropogenic CO_2 emissions (billion metric tons C)	0.39	0.82	0.23	0.20	0.16	0.08
Share of total emissions due to land use change (%)	83.29	-1.60	-3.08	66.91	40.19	-1.49

Per Capita 1994	Brazil	China	India	Indonesia	Mexico	South Africa
PPP GDP (87 int'l$/capita)	4520	2124	1099	2332	6293	5030
Real GDP (87 $us/capita)	2019	438	407	676	1891	2141
Combustion emissions (metric tons C/capita)	0.41	0.70	0.26	0.35	1.08	2.11
Land use change emissions (metric tons C/capita)	2.04	-0.01	-0.01	0.71	0.73	-0.03
Total Anthropogenic emissions (metric tons C/capita)	2.45	0.68	0.25	1.06	1.81	2.08

Table 9 Key Countries Summary Information

Per unit GDP 1994	Brazil	China	India	Indonesia	Mexico	South Africa
Combustion emissions (metric tons C per millions of 1987 PPP $)	91	327	236	151	172	419
Land use change emissions (metric tons C per millions of 1987 PPP $)	452	-5	-7	305	116	-6
Total Antropogenic emissions (metric tons C per millions of 1987 PPP $)	543	322	228	456	288	413

World Shares 1994 (%)	Brazil	China	India	Indonesia	Mexico	South Africa
Population	2.89	21.91	16.81	3.50	1.66	0.75
PPP GDP	3.05	10.88	4.32	1.91	2.44	0.88
Real GDP	1.79	2.94	2.10	0.73	0.96	0.49
Combustion emissions	1.22	15.63	4.46	1.26	1.84	1.61
Land-use change emissions	23.62	-0.96	-0.52	9.96	4.83	-0.09
Total anthropogenic CO2 emissions	5.79	12.24	3.44	3.04	2.45	1.26

Annual Growth Rates 1990-1994 (%)	Brazil	China	India	Indonesia	Mexico	South Africa
Population	1.54	1.23	1.89	1.71	2.01	2.34
PPP GDP	0.21	15.48	5.09	8.61	3.64	0.20
Real GDP	2.45	15.36	4.23	8.63	2.77	0.00
Combustion emissions	4.84	7.44	6.82	3.76	3.54	1.64

Table 10 Fossil Fuel Emmissions Elasticities;
Random Country Effects

Explanatory Variables	World
1985 $ PPP GDP per capita spline 1 *	1.9533
	(4.08)
1985 $ PPP GDP per capita spline 2 *	0.0660
	(0.33)
1985 $ PPP GDP per capita spline 3 *	1.1749
	(10.09)
1985 $ PPP GDP per capita spline 4 *	1.2524
	12.88
1985 $ PPP GDP per capita spline 5 *	0.9464
	10.83
1985 $ PPP GDP per capita spline 6 *	1.4270
	16.37
1985 $ PPP GDP per capita spline 7 *	0.6514
	6.64
1985 $ PPP GDP per capita spline 8 *	0.6130
	5.70
1985 $ PPP GDP per capita spline 9 *	-0.1893
	(1.97)
1985 $ PPP GDP per capita spline 10 *	-0.1204
	(0.69)
% of people in temperate climate	1.0743
	6.38
% of people in wet-dry climate	-0.5238
	(3.12)
% of people in snow-ice climate	1.5222
	5.61
% of energy production from hydro	-0.8626
	(3.94)
Oil exporters	0.2407
	2.25
Socialist Countries	0.1365
	2.94
Constant	-21.5180
	(7.58)
R-sq within = 0.6798	
between = 0.8735	
overall = 0.8581	
Numer of Observations	2592
Number of Countries	85

* Actual variables in regression expressed as natural logs.

Table 11 Hausman Specification Test
Ho: Random Country Effects is the Correct Specification

LHS Time-variant variable	Fixed Effects	Random Effects	Difference
1985 $ PPP GDP per capita spline 1 *	1.519	1.953	-0.434
1985 $ PPP GDP per capita spline 2 *	-0.003	0.066	-0.069
1985 $ PPP GDP per capita spline 3 *	1.131	1.175	-0.044
1985 $ PPP GDP per capita spline 4 *	1.224	1.252	-0.028
1985 $ PPP GDP per capita spline 5 *	0.896	0.946	-0.051
1985 $ PPP GDP per capita spline 6 *	1.379	1.427	-0.048
1985 $ PPP GDP per capita spline 7 *	0.623	0.651	-0.028
1985 $ PPP GDP per capita spline 8 *	0.539	0.613	-0.074
1985 $ PPP GDP per capita spline 9 *	-0.238	-0.189	-0.049
1985 $ PPP GDP per capita spline 10 *	-0.187	-0.120	-0.067
year 1962	0.022	0.022	0.000
year 1963	0.025	0.022	0.003
year 1964	0.048	0.043	0.005
year 1965	0.112	0.105	0.007
year 1966	0.148	0.139	0.009
year 1967	0.191	0.181	0.010
year 1968	0.189	0.178	0.011
year 1969	0.255	0.242	0.013
year 1970	0.284	0.268	0.015
year 1971	0.508	0.491	0.017
year 1972	0.523	0.504	0.019
year 1973	0.539	0.517	0.021
year 1974	0.608	0.585	0.023
year 1975	0.577	0.552	0.024
year 1976	0.549	0.524	0.025
year 1977	0.568	0.541	0.026
year 1978	0.544	0.517	0.028
year 1979	0.571	0.542	0.029
year 1980	0.575	0.545	0.030
year 1981	0.576	0.546	0.030
year 1982	0.543	0.513	0.030
year 1983	0.525	0.495	0.030
year 1984	0.553	0.523	0.030
year 1985	0.541	0.511	0.030
year 1986	0.528	0.498	0.030
year 1987	0.529	0.498	0.031
year 1988	0.540	0.509	0.031
year 1989	0.535	0.503	0.032
year 1990	0.507	0.475	0.032
year 1991	0.589	0.555	0.033
year 1992	0.590	0.556	0.034
year 1993	0.707	0.671	0.036

Test: Ho: difference in coefficients not systematic

chi2(43) = (b-B)'[S^(-1)](b-B), S = (S_fe - S_re)

$\qquad$ =   96.27

Prob>chi2 =   0.0000 $\qquad$ Reject Ho

Table 12 Fossil Fuel Emissions Elasticities;
Controlling For Country and Time Fixed Effects

Explanatory Variables	Obs. In Spline	Max. Income in Spline	World
1985 $ PPP GDP per capita spline 1 *	4086	$ 393	0.2694
			0.58
1985 $ PPP GDP per capita spline 2 *	4018	$ 601	0.7867
			5.70
1985 $ PPP GDP per capita spline 3 *	3680	$ 921	0.6283
			6.35
1985 $ PPP GDP per capita spline 4 *	3114	$ 1,410	1.0475
			10.69
1985 $ PPP GDP per capita spline 5 *	2508	$ 2,156	0.9081
			10.13
1985 $ PPP GDP per capita spline 6 *	1972	$ 3,301	1.0217
			11.80
1985 $ PPP GDP per capita spline 7 *	1482	$ 5,049	0.4517
			4.61
1985 $ PPP GDP per capita spline 8 *	1023	$ 7,731	0.5035
			4.82
1985 $ PPP GDP per capita spline 9 *	640	$ 11,825	(0.3905)
			(4.03)
1985 $ PPP GDP per capita spline 10 *	252	$ 18,088	(0.4985)
			(2.68)
Constant			-11.8180
			(4.28)
R-sq within			0.6077
between			0.8079
overall			0.7442
Numer of Observations			3869
Number of Countries			127

* Actual variables in regression expressed as natural logs.

Income Elasticities of Emissions - 10 Segement Spline, Country and Time Fixed Effects
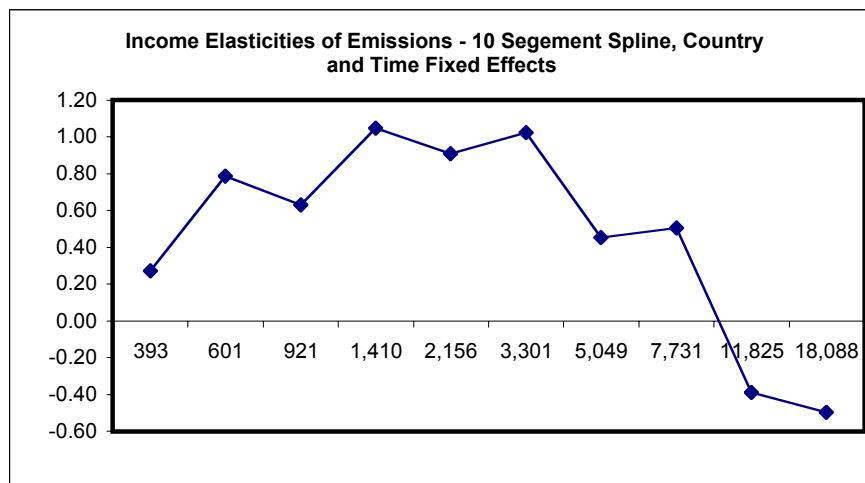
Table 13 Fossil Fuel Emissions Elasticities;

Controlling For Country Fixed Effects, including prices

	OECD
1985 $ PPP GDP per capita spline 1 *	(dropped)
1985 $ PPP GDP per capita spline 2 *	(dropped)
1985 $ PPP GDP per capita spline 3 *	(dropped)
1985 $ PPP GDP per capita spline 4 *	(dropped)
1985 $ PPP GDP per capita spline 5 *	(dropped)
1985 $ PPP GDP per capita spline 6 *	(dropped)
1985 $ PPP GDP per capita spline 7 *	0.8883
	2.50
1985 $ PPP GDP per capita spline 8 *	1.0763
	5.17
1985 $ PPP GDP per capita spline 9 *	0.6285
	2.62
1985 $ PPP GDP per capita spline 10 *	0.9188
	5.06
Energy price (1985 PPP$/ toe) *	(0.0258)
	(0.68)
Annual renewable energy consumption per capita (mtoe/cap) *	0.0097
	0.5
R-sq within = 0.5564	
between = 0.5688	
overall = 0.5601	
Numer of Observations	102
Number of Countries	21

* Actual variables in regression expressed as natural logs.

Table 14 Fossil Fuel Emissions Elasticities;

Forecast Equation

Explanatory Variables	World
1985 $ PPP GDP per capita spline 1 *	0.2694
	0.5790
1985 $ PPP GDP per capita spline 2 *	0.7867
	5.7020
1985 $ PPP GDP per capita spline 3 *	0.6283
	6.3450
1985 $ PPP GDP per capita spline 4 *	1.0475
	10.6910
1985 $ PPP GDP per capita spline 5 *	0.9081
	10.1320
1985 $ PPP GDP per capita spline 6 *	1.0217
	11.8000
1985 $ PPP GDP per capita spline 7 *	0.4517
	4.6060
1985 $ PPP GDP per capita spline 8 *	0.5035
	4.8210
1985 $ PPP GDP per capita spline 9 *	(0.3905)
	(4.0300)
1985 $ PPP GDP per capita spline 10 *	(0.4985)
	(2.6830)
Time**	(0.01)
	(3.84)

* Actual variables in regression expressed as natural logs.

** Source: within regession (country fixed effects) for OECD, including a real energy price variable.
   The coeffienct on energy price in this regression is -.023 and the t-statistic is 1.37.
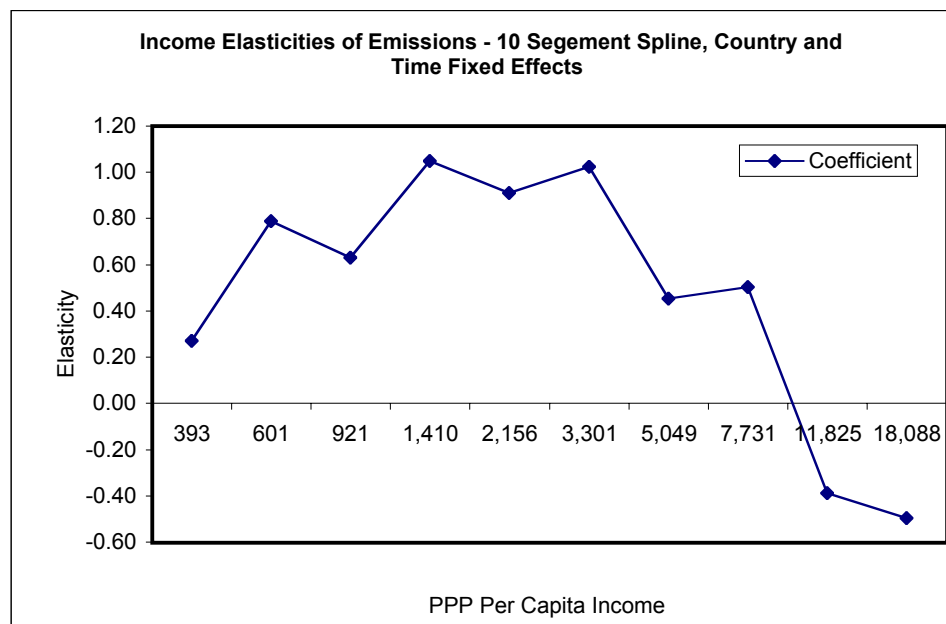
Income Elasticities of Emissions - 10 Segement Spline, Country and Time Fixed Effects

Table 14a **Country Fixed Effects**

Countries in income-only regression	Country-specific fixed effects in Income only regression
Nepal	-0.19
Laos	0.00
Burundi	0.03
Burkina Faso	0.64
Bangladesh	0.69
Ethiopia	0.73
Mali	0.81
Niger	0.88
Central African Republic	0.91
Benin	0.94
Haiti	1.22
Comoros	1.27
Malawi	1.37
Cameroon	1.47
The Gambia	1.53
Sri Lanka	1.54
Mozambique	1.56
Mauritius	1.60
Guinea-Bissau	1.64
Swaziland	1.76
Guatemala	1.84
Slovenia	1.85
Myanmar (Burma)	1.90
Congo	1.93
Cape Verde	1.94
Ghana	1.98
Costa Rica	2.00
Ivory Coast	2.01
Guinea	2.02
Fiji	2.16
Nicaragua	2.17
Kenya	2.20
Pakistan	2.22
Botswana	2.23
Honduras	2.27
Brazil	2.33
Morocco	2.35
Mauritania	2.35
Philippines	2.38
Bolivia	2.39
Ecuador	2.46
Indonesia	2.46
Peru	2.49
Uruguay	2.52
Dominican Republic	2.56
Panama	2.63
Nigeria	2.65
India	2.66

Table 14a **Country Fixed Effects**

Countries in income-only regression	Country-specific fixed effects in Income only regression
Angola	2.68
Djibouti	2.68
Colombia	2.74
Malaysia	2.75
Turkey	2.77
Iraq	2.79
Liberia	2.84
Portugal	2.86
Hong Kong	2.87
Mexico	2.90
Chile	2.90
Jordan	2.95
Egypt	2.99
Algeria	3.02
Argentina	3.03
Iran	3.09
Spain	3.13
Gabon	3.25
Korea	3.27
Greece	3.28
Cyprus	3.32
Israel	3.42
Jamaica	3.43
Italy	3.46
Guyana	3.46
New Zealand	3.53
China	3.66
Switzerland	3.67
Austria	3.69
Japan	3.69
Ireland	3.73
Hungary	3.75
Iceland	3.80
France	3.83
Bulgaria	3.89
Finland	3.92
Sweden	3.95
Netherlands	3.98
Norway	4.01
Mongolia	4.11
United Kingdom	4.15
Denmark	4.18
Former Yugoslavia	4.19
Belgium	4.24
Poland	4.27
West Germany	4.27
Australia	4.31
East Germany	4.51
Canada	4.53
United States	4.89
Romania	5.13
Luxembourg	5.26

Table 15 Tropical World Summary Forestry Statistics

Tropical World	1991 WRI Emissions from Land Use (bill tons of carbon)	1990 Houghton Emissions from Land Use (bill tons of carbon)	Total Biomass (tons/ha)	Total Forest 1990 (000 ha)	Total Forest 1995 (000 ha)	Change 1990-1995 (000 ha)	Rate of Change
Central America	0.052	0.070	157	84,628	79,443	-5,185	-6.1%
South America	0.459	0.503	189	851,223	827,946	-23,277	-2.7%
Africa	0.195	0.342	133	523,376	504,901	-18,475	-3.5%
Asia	0.272	0.679	188	295,041	279,766	-15,275	-5.2%
Oceania	0.010	0.020	191	42,659	41,903	-756	-1.8%
Total	0.988	1.614		1,796,927	1,733,959	-62,968	-3.5%

Tropical World	1994 Fuelwood Production (000 m3)	1994 Fuelwood Imports (000 m3)	1994 Fuelwood Exports (000 m3)	Consumption (000 ha)**
Central America	62,028	33	79	395
South America	239,354	4	92	1,266
Africa	483,933	4	162	3,637
Asia	648,448	295	2,003	3,440
Oceania	5,802	0	0	30
Total	1,439,565	336	2,336	8,769

	1994 Roundwood Production (000 m3)	1994 Roundwood Imports (000 m3)	1994 Roundwood Exports (000 m3)	Consumption (000 ha)**
Central America	10,108	159	235	64
South America	90,512	38	1,754	470
Africa	45,425	86	4,853	306
Asia	117,845	2,880	11,038	583
Oceania	3,345	2	4,019	(4)
Total	267,235	3,165	21,899	1,419

	1994 Sawnwood Production (000 m3)	1994 Sawnwood Imports (000 m3)	1994 Sawnwood Exports (000 m3)	Consumption (000 ha)**
Central America	4,680	2,091	909	37
South America	21,396	180	1,709	105
Africa	6,222	185	1,387	38
Asia	38,963	3,573	6,278	193
Oceania	276	75	45	2
Total	71,537	6,104	10,328	375

* Source:Emissions data WRI (1997), Houghton et al (1994); Forestry data FAO (1993), FAO (1997)

** Assumes biomass as listed above.

Table 15a Characteristics of Major Source Countries for Land Use Change Emissions

Country	1991 WRI emissions from land use (bill tons of carbon)	Natural forest biomass (tons/ha)	Closed broadleaf forest ave. logging intensity 1981-90 (m3/ha)	Total forest 1990 (000 ha)	Total forest 1995 (000 ha)	Change 1990-1995 (000 ha)	Percentage change 1990-1995
Bolivia	0.04	150	13	51,217	48,310	-2,907	-5.7%
Indonesia	0.11	203	20	115,213	109,791	-5,422	-4.7%
Brazil	0.30	189	6	563,911	551,139	-12,772	-2.3%
Columbia	0.03	195	16	54,299	52,988	-1,311	-2.4%
Venezuela	0.05	189	11	46,512	43,995	-2,517	-5.4%
Democratic Rep. Congo	0.08	252	15	112,946	109,245	-3,701	-3.3%
Myanmar (Burma)	0.04	217	14	29,088	27,151	-1,937	-6.7%
Malaysia	0.06	261	75	17,472	15,471	-2,001	-11.5%
Phillippines	0.03	236	83	8,078	6,766	-1,312	-16.2%

* Source:Emissions data WRI (1997), Houghton et al (1994); Forestry data FAO (1993), FAO (1997)

Table 15b Temperate World Summary Forestry Statistics

Non-Tropical World	1991 WRI Emissions from Land Use (bill tons of carbon)	1990 Houghton Emissions from Land Use (bill tons of carbon)	Total Forest 1990 (000 ha)	Total Forest 1995 (000 ha)	Change 1990-1995 (000 ha)	Rate of Change
Temperate Africa	0.004	--	15,602	15,336	-266	-1.7%
Temperate Asia	0.042	--	195,771	194,406	-1,365	-0.7%
Temperate Oceania	--	--	48,490	48,792	302	0.6%
W. Europe	0.003	--	57,688	59,479	1,791	3.1%
E. Europe	--	--	83,739	86,638	2,899	3.5%
Russia	--	--	763,500	763,500	0	0.0%
North America	--	--	453,270	457,086	3,816	0.8%
Temperate South America	0.033	--	43,243	42,648	-595	-1.4%
Total	0.036		1,401,440	1,409,351	7,911	0.6%

Non-Tropical World	1994 Fuelwood Production (000 m3)	1994 Fuelwood Imports (000 m3)	1994 Fuelwood Exports (000 m3)	Consumption (000 ha)**
Temperate Africa	18,320	303	177	132
Temperate Asia	230,533	1,121	169	1,653
Temperate Oceania	2,948	3	7	21
W. Europe	39,019	2,447	840	290
E. Europe	12,074	12	920	80
Former Soviet Union	30,800	3	236	408
North America	98,920	712	732	706
Temperate South America	18,838	4	107	134
Total	199,651	3,178	2,835	1,618

Non-Tropical World	1994 Roundwood Production (000 m3)	1994 Roundwood Imports (000 m3)	1994 Roundwood Exports (000 m3)	Consumption (000 ha)**
Temperate Africa	20,054	639	2,092	133
Temperate Asia	143,854	62,999	2,631	1,459
Temperate Oceania	35,445	14	12,848	162
W. Europe	228,958	47,151	20,953	1,823
E. Europe	50,396	797	4,171	336
Former Soviet Union	112,413	144	19,680	1,238
North America	580,779	7,698	21,946	4,047
Temperate South America	28,291	10	7,198	151
Total	1,000,837	55,800	73,948	7,594

Non-Tropical World	1994 Sawnwood Production (000 m3)	1994 Sawnwood Imports (000 m3)	1994 Sawnwood Exports (000 m3)	Consumption (000 ha)**
Temperate Africa	1,787	2,298	45	29
Temperate Asia	59,630	16,869	1,043	539
Temperate Oceania	6,348	1,116	1,090	46
W. Europe	70,144	36,404	28,462	558
E. Europe	12,022	1,126	4,496	62
Former Soviet Union	31,465	159	8,087	314
North America	155,753	40,555	52,956	1,024
Temperate South America	4,631	117	2,713	15
Total	274,015	78,361	96,714	1,972

* Source:Emissions data WRI (1997), Houghton et al (1994); Forestry data FAO (1993), FAO (1997)

** Assumes biomass of 140 tons/ha for all but Russia/ Soviet Union. There assume 75 tons/ha.

	Central America	South America	Africa	Asia	Oceania	Total
Table 15c Tropical Deforestation Scenarios						
Tropical Forest 1995 000 ha	79,443	870,594	504,901	279,766	41,903	1,776,607
Estimated Biomass (tons/ha)	200	189	133	181	191	
Tropical Forest metric tons	15,888,600,000	164,542,266,000	67,151,833,000	50,637,646,000	8,003,473,000	306,223,818,000
Carbon content (.45* metric tons)	7,149,870,000	74,044,019,700	30,218,324,850	22,786,940,700	3,601,562,850	137,800,718,100
Annual cut if 25% deforested in 2045 (tons of carbon)	35,048,382	370,220,099	151,091,624	113,934,704	18,007,814	689,003,591
Annual cut if 50% deforested in 2045 (tons of carbon)	71,498,700	740,440,197	302,183,249	227,869,407	36,015,629	1,378,007,181
Annual cut if 75% deforested in 2045 (tons of carbon)	107,248,050	1,110,660,296	453,274,873	341,804,111	54,023,443	2,067,010,772
Annual cut if 100% deforested in 2045 (tons of carbon)	142,997,400	1,480,880,394	604,366,497	455,738,814	72,031,257	2,756,014,362
Est. Annual emissions if 25% deforested in 2045 (bill. of carbon)	0.03	0.28	0.11	0.09	0.01	0.52
Est. Annual emissions if 50% deforested in 2045 (bill. of carbon)	0.05	0.56	0.23	0.17	0.03	1.03
Est. Annual emissions if 75% deforested in 2045 (bill. of carbon)	0.08	0.83	0.34	0.26	0.04	1.55
Est. Annual emissions if 100% deforested in 2045 (bill. of carbon)	0.11	1.11	0.45	0.34	0.05	2.07
Stock in 2045 from deforstation of 25% of tropical forest						21.71
Stock in 2045 from deforstation of 50% of tropical forest						43.42
Stock in 2045 from deforstation of 75% of tropical forest						65.13
Stock in 2045 from deforstation of 100% of tropical forest						86.84

Table 16 Explanation of Developing Countries' Land Use Emissions 1991

Explanatory Variables	World
Population density*	1.103
	3.37
Population density squared*	-0.131
	2.79
Annual percentage change in population density	7.80
	2.20
1990 forest cover per hectare*	0.740
	9.42
Asia dummy	1.004
	3.45
Latin America dummy	1.504
	7.51
% of land in temperate climate zone	-1.089
	2.69
% of people in rainforest climate zone	1.066
	2.90
constant	-6.225
	10.94
Number of Observations	63
R-squared	0.819

* Actual variables in regression expressed as natural logs.

Table 17 Estimated Flows of CO2 Emissions from Land Use Change 1860-1990 (Billion tons of C)

Country Group	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990
Japan	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.05	0.03	-0.02	-0.04
USA	0.15	0.17	0.20	0.19	0.18	0.16	0.15	0.13	0.05	0.00	-0.03	-0.05	-0.06	-0.07
EU	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03	0.09	0.06	0.03	0.01	-0.03	-0.09	-0.09
Other High Income	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.04	0.03	0.01	0.03
High Income OPEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Middle Income	-0.01	-0.01	-0.02	-0.01	-0.02	-0.01	-0.02	0.08	0.09	0.10	0.17	0.32	0.46	0.54
Russia	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.05	0.03	0.10	0.09	0.05	0.00
Lower Middle Income	0.10	0.11	0.09	0.15	0.13	0.25	0.16	0.15	0.18	0.25	0.27	0.32	0.33	0.27
Eastern Europe	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.05	0.04	0.02	0.00
Low Income	0.11	0.12	0.14	0.14	0.17	0.19	0.15	0.09	0.10	0.17	0.19	0.28	0.36	0.41
China	0.06	0.06	0.05	0.05	0.05	0.05	0.06	0.07	0.07	0.08	0.12	0.15	0.08	0.04
India	0.02	0.03	0.03	0.03	0.04	0.04	0.03	0.01	0.01	0.02	0.01	0.02	0.02	0.02
Africa	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.06	0.10	0.15	0.24	0.34
TOTAL	0.45	0.49	0.53	0.59	0.60	0.74	0.62	0.73	0.71	0.77	1.08	1.36	1.42	1.46

Table 18 Stock of CO2 Emissions from Land Use Change 1860-1990 (Billion tons of C)

Country Group	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990
Japan	0.00	0.01	0.09	0.17	0.26	0.35	0.46	0.56	0.67	0.77	1.13	1.34	1.18	0.79
USA	0.15	1.53	2.82	3.94	4.84	5.55	6.09	6.70	6.58	6.00	5.27	4.51	3.82	3.12
EU	-0.02	-0.22	-0.34	-0.43	-0.53	-0.64	-0.77	0.10	0.64	0.81	0.77	0.54	-0.04	-0.77
Other High Income	0.02	0.20	0.42	0.62	0.80	0.95	1.09	1.01	1.02	1.06	1.27	1.44	1.42	1.45
High Income OPEC	0.00	0.01	0.02	0.03	0.04	0.06	0.07	0.06	0.05	0.05	0.05	0.07	0.15	0.24
Middle Income	-0.01	-0.14	-0.25	-0.29	-0.38	-0.37	-0.45	0.22	0.88	1.46	2.53	4.38	6.79	9.98
Russia	0.02	0.18	0.30	0.41	0.50	0.58	0.73	0.99	1.27	1.37	2.16	2.73	2.85	2.68
Lower Middle Income	0.10	1.02	1.60	2.48	3.14	4.61	5.31	5.76	6.43	7.44	8.89	10.51	11.75	12.80
Eastern Europe	-0.01	-0.09	-0.14	-0.16	-0.20	-0.26	-0.29	-0.20	-0.08	0.00	0.44	0.74	0.81	0.71
Low Income	0.11	1.14	2.05	2.84	3.77	4.71	5.44	5.44	5.60	6.12	7.12	8.48	10.05	12.12
China	0.06	0.54	0.88	1.12	1.34	1.54	1.82	2.14	2.46	2.78	3.29	4.07	4.39	4.34
India	0.02	0.24	0.42	0.59	0.78	0.98	1.13	1.02	0.97	0.97	1.00	1.06	1.13	1.20
Africa	0.01	0.08	0.14	0.21	0.28	0.38	0.52	0.70	0.91	1.28	1.88	2.82	4.15	6.07
TOTAL	0.45	4.51	8.03	11.53	14.65	18.45	21.14	24.49	27.41	30.12	35.79	42.71	48.44	54.73

Table 19 CO2 Emissions Flows from Fossil Fuels 1860-1996 (Billion tons of C)

Country Group	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	1996
Japan	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.03	0.06	0.20	0.25	0.29	0.32
USA	0.01	0.03	0.05	0.11	0.18	0.35	0.47	0.47	0.51	0.69	0.80	1.15	1.25	1.32	1.45
EU	0.07	0.11	0.16	0.21	0.28	0.35	0.33	0.40	0.42	0.42	0.61	0.86	0.96	0.85	0.85
Other High Income	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.06	0.08	0.15	0.20	0.22	0.25
High Income OPEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.10	0.13
Middle Income	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.08	0.14	0.18	0.27
Russia	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.08	0.11	0.24	0.38	0.56	0.61	0.43
Lower Middle Income	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.05	0.11	0.19	0.31	0.44	0.57
Eastern Europe	0.00	0.01	0.01	0.02	0.04	0.05	0.04	0.05	0.13	0.13	0.26	0.42	0.61	0.55	0.36
Low Income	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.05	0.11	0.18	0.26	0.31
China	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.21	0.21	0.40	0.66	0.92
India	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.09	0.18	0.27
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.05
TOTAL	0.09	0.15	0.23	0.35	0.53	0.83	0.93	1.06	1.32	1.58	2.50	3.85	5.05	5.71	6.18

Table 20 Stock of CO2 Emissions from Fossil Fuels 1860-1996 (Billion tons of C)

Country Group	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	1996
Japan	0.00	0.00	0.00	0.01	0.04	0.11	0.23	0.39	0.60	0.74	1.02	1.96	3.72	5.26	6.35
USA	0.01	0.17	0.48	1.09	2.09	4.09	6.86	9.68	11.67	15.33	19.41	25.03	31.96	37.98	40.55
EU	0.07	0.90	1.87	3.07	4.54	6.47	8.37	10.23	12.09	13.57	16.43	20.72	25.77	29.51	31.43
Other High Income	0.00	0.00	0.01	0.04	0.09	0.20	0.41	0.61	0.78	1.11	1.56	2.31	3.49	4.69	5.50
High Income OPEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.05	0.20	0.60	1.17	1.80
Middle Income	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.10	0.20	0.22	0.45	0.84	1.64	2.67	3.63
Russia	0.00	0.00	0.01	0.04	0.10	0.20	0.28	0.35	0.77	1.29	2.64	4.94	8.27	12.09	13.40
Lower Middle Income	0.00	0.00	0.00	0.00	0.02	0.06	0.13	0.23	0.37	0.63	1.26	2.29	4.15	6.66	8.86
Eastern Europe	0.00	0.05	0.14	0.28	0.50	0.82	1.12	1.33	1.74	2.46	3.84	6.28	9.87	13.42	14.20
Low Income	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.08	0.17	0.26	0.55	1.18	2.23	3.74	4.89
China	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.13	0.24	0.35	1.10	2.10	4.57	8.44	11.80
India	0.00	0.00	0.00	0.01	0.03	0.07	0.15	0.23	0.31	0.40	0.56	0.87	1.37	2.38	3.37
Africa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.08	0.18	0.42	0.69	0.89
TOTAL	0.09	1.13	2.52	4.55	7.43	12.12	17.74	23.37	28.94	36.46	48.96	68.88	98.06	128.70	146.68

Table 21 Projected Flows of CO2 Emissions from Fossil Fuels 1996-2050 (Billion tons of C)

Country Group	1996	2000	2010	2020	2030	2040	2050
Japan	0.32	0.30	0.26	0.22	0.18	0.15	0.12
USA	1.45	1.42	1.33	1.24	1.12	0.98	0.85
EU	0.85	0.81	0.70	0.60	0.51	0.42	0.34
Other High Income	0.26	0.26	0.24	0.23	0.21	0.18	0.15
High Income OPEC	0.12	0.13	0.13	0.11	0.10	0.08	0.07
Middle Income	0.27	0.29	0.34	0.33	0.31	0.27	0.23
Russia	0.43	0.45	0.48	0.40	0.32	0.25	0.19
Lower Middle Income	0.57	0.63	0.80	0.90	0.84	0.76	0.66
Eastern Europe	0.36	0.38	0.41	0.38	0.31	0.25	0.20
Low Income	0.31	0.38	0.63	0.84	1.02	1.21	1.09
China	0.92	1.14	1.92	2.34	2.75	2.26	1.79
India	0.27	0.34	0.58	0.78	0.94	0.97	0.83
Africa	0.05	0.07	0.12	0.21	0.31	0.39	0.47
TOTAL	6.18	6.59	7.96	8.59	8.92	8.16	7.01

Table 22 Projected Stock of CO2 Emissions from Fossil Fuels 1996-2050(Billion tons of C)

Country Group	1996	2000	2010	2020	2030	2040	2050
Japan	6.35	7.02	8.30	9.12	9.60	9.82	9.88
USA	40.55	43.32	49.11	53.66	57.10	59.34	60.56
EU	31.43	32.66	34.93	36.28	36.92	36.98	36.58
Other High Income	5.50	6.07	7.28	8.24	8.99	9.49	9.79
High Income OPEC	1.80	2.12	2.85	3.39	3.78	4.02	4.15
Middle Income	3.63	4.40	6.41	8.29	9.71	10.75	11.45
Russia	13.40	14.05	15.93	17.48	18.22	18.39	18.22
Lower Middle Income	8.86	10.42	14.89	20.06	24.33	27.53	29.76
Eastern Europe	14.20	14.61	15.93	17.30	18.04	18.28	18.19
Low Income	4.89	5.84	9.29	14.27	20.01	26.51	32.15
China	11.80	14.79	25.69	39.79	55.20	67.28	74.06
India	3.37	4.29	7.62	12.38	17.71	23.30	27.26
Africa	0.89	1.04	1.69	2.86	4.74	7.00	9.60
TOTAL	146.68	160.63	199.93	243.11	284.32	318.70	341.65

Table 23 Projected Flows of CO2 Emissions from Land Use Change 1990-2050 (Billions of tons of C)

Country Group	1990	2000	2010	2020	2030	2040	2050
Japan	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03
USA	-0.07	-0.07	-0.08	-0.08	-0.08	-0.08	-0.08
EU	-0.09	-0.09	-0.09	-0.09	-0.08	-0.08	-0.07
Other High Income	0.03	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
High Income OPEC	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Middle Income	0.54	0.54	0.53	0.50	0.46	0.42	0.38
Russia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Middle Income	0.27	0.27	0.25	0.23	0.20	0.17	0.15
Eastern Europe	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low Income	0.41	0.39	0.35	0.30	0.25	0.20	0.15
China	0.04	0.04	0.04	0.03	0.03	0.03	0.03
India	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Africa	0.34	0.36	0.40	0.40	0.38	0.34	0.30
TOTAL	1.46	1.41	1.37	1.28	1.15	0.99	0.84

Table 24 Projected Stocks of CO2 Emissions from Land Use Change 1990-2050(Billions of tons of C)

Country Group	1990	2000	2010	2020	2030	2040	2050
Japan	0.79	0.38	0.05	-0.20	-0.40	-0.57	-0.71
USA	3.12	2.49	1.89	1.31	0.76	0.27	-0.18
EU	-0.77	-1.34	-1.81	-2.23	-2.59	-2.88	-3.12
Other High Income	1.45	1.22	1.05	0.91	0.79	0.69	0.60
High Income OPEC	0.24	0.29	0.31	0.34	0.36	0.38	0.39
Middle Income	9.98	12.97	15.48	17.58	19.27	20.56	21.48
Russia	2.68	2.42	2.23	2.09	1.98	1.87	1.78
Lower Middle Income	12.80	13.56	14.24	14.74	15.03	15.13	15.06
Eastern Europe	0.71	0.58	0.50	0.43	0.38	0.34	0.31
Low Income	12.12	13.97	15.33	16.20	16.63	16.69	16.47
China	4.34	4.20	4.11	4.05	3.98	3.91	3.83
India	1.20	1.26	1.32	1.39	1.45	1.51	1.56
Africa	6.07	8.12	10.15	12.08	13.74	14.96	15.76
TOTAL	54.73	60.12	64.85	68.69	71.38	72.86	73.23

Table 25 Historic Stocks of CO2 Emissions from Fossil Fuels & Land Use Change 1860-1990 (Billions of tons of C)

Country Group	1860	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990
Japan	0.00	0.02	0.09	0.18	0.30	0.46	0.69	0.95	1.26	1.51	2.15	3.30	4.89	6.05
USA	0.16	1.70	3.30	5.04	6.93	9.64	12.95	16.37	18.25	21.33	24.68	29.54	35.78	41.10
EU	0.05	0.68	1.53	2.64	4.01	5.83	7.60	10.33	12.72	14.38	17.20	21.25	25.73	28.74
Other High Income	0.02	0.21	0.43	0.66	0.88	1.15	1.49	1.62	1.80	2.17	2.83	3.75	4.91	6.14
High Income OPEC	0.00	0.01	0.02	0.03	0.04	0.06	0.07	0.06	0.06	0.09	0.09	0.27	0.75	1.41
Middle Income	-0.01	-0.14	-0.25	-0.29	-0.37	-0.34	-0.39	0.32	1.08	1.69	2.98	5.22	8.43	12.64
Russia	0.02	0.18	0.32	0.45	0.60	0.79	1.01	1.34	2.03	2.66	4.80	7.67	11.13	14.77
Lower Middle Income	0.10	1.02	1.61	2.48	3.16	4.67	5.44	5.99	6.80	8.08	10.14	12.80	15.89	19.47
Eastern Europe	-0.01	-0.05	0.00	0.12	0.30	0.56	0.83	1.13	1.66	2.45	4.27	7.03	10.68	14.13
Low Income	0.11	1.14	2.05	2.85	3.78	4.74	5.49	5.52	5.77	6.38	7.68	9.66	12.28	15.85
China	0.06	0.54	0.88	1.12	1.34	1.57	1.88	2.27	2.70	3.14	4.39	6.17	8.96	12.79
India	0.02	0.24	0.43	0.60	0.81	1.05	1.28	1.25	1.27	1.37	1.56	1.92	2.50	3.58
Africa	0.01	0.08	0.14	0.21	0.28	0.38	0.52	0.71	0.93	1.31	1.96	3.00	4.57	6.76
TOTAL	0.54	5.64	10.55	16.09	22.08	30.57	38.88	47.85	56.35	66.58	84.74	111.59	146.50	183.44

Table 26 Projected Stocks of CO2 Emissions from Fossil Fuels & Land use 1990-2050(Billions of tons of C)

Country Group	1990	2000	2010	2020	2030	2040	2050
Japan	6.05	7.40	8.36	8.92	9.19	9.25	9.17
USA	41.10	45.81	51.00	54.96	57.86	59.61	60.38
EU	28.74	31.33	33.12	34.05	34.33	34.09	33.46
Other High Income	6.14	7.29	8.33	9.15	9.78	10.18	10.39
High Income OPEC	1.41	2.41	3.16	3.73	4.14	4.40	4.55
Middle Income	12.64	17.37	21.90	25.87	28.98	31.31	32.93
Russia	14.77	16.47	18.16	19.57	20.19	20.27	20.00
Lower Middle Income	19.47	23.98	29.13	34.79	39.36	42.66	44.82
Eastern Europe	14.13	15.19	16.43	17.73	18.42	18.62	18.50
Low Income	15.85	19.81	24.62	30.47	36.64	43.20	48.63
China	12.79	18.99	29.80	43.83	59.19	71.20	77.89
India	3.58	5.54	8.95	13.77	19.16	24.81	28.82
Africa	6.76	9.17	11.84	14.95	18.47	21.96	25.36
TOTAL	183.44	220.75	264.78	311.80	355.70	391.56	414.88

Table 27 Damages Associated With CO2 Emissions By Region

	2045 Population (Thousands)	PPP Forecast GDP 2045 (Millions)	Damages as percentage of own GDP	Damages as percentage of world damage	Contribution to Stock of CO2 as percentage of total stock	Net transfer as percentage of World GDP	Net transfer as percentage of own GDP
Japan	106,391	4,011,585	-0.01%	0.0%	3.0%	-0.04%	-1.14%
USA	312,983	12,815,233	0.05%	0.4%	18.1%	-0.24%	-2.09%
EU	332,417	11,596,737	1.54%	11.8%	11.1%	0.01%	0.09%
Other High Income	78,474	2,619,915	-1.01%	-1.7%	2.9%	-0.06%	-2.69%
High Income OPEC	16,980	370,618	1.42%	0.3%	1.2%	-0.01%	-3.63%
Middle Income	355,720	5,440,169	1.31%	4.7%	3.4%	0.02%	0.37%
Russia	109,934	2,092,953	-1.15%	-1.6%	5.5%	-0.10%	-5.15%
Lower Middle Income	936,978	14,663,390	1.40%	13.6%	8.7%	0.07%	0.51%
Eastern Europe	161,521	2,832,811	-0.44%	-0.8%	5.5%	-0.09%	-3.39%
Low Income	1,719,230	15,239,445	2.25%	22.7%	8.9%	0.19%	1.37%
China	1,385,457	17,751,105	-0.17%	-2.0%	21.5%	-0.32%	-2.00%
India	1,375,622	14,052,243	3.35%	31.1%	7.7%	0.32%	2.52%
Africa	1,427,028	8,740,153	3.75%	21.6%	2.5%	0.26%	3.31%
Total	8,318,733	112,226,358	1.35%				

VIII. Figures